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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAYWORTH.

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THE NAPIER TERCENTENARY.

In the history of science we meet with reputations so thoroughly established that no scheme of commemoration or similar device can enhance our estimate of their services or add to their well-earned renown. The grasp of some fundamental truth has been so complete, the treatment of it exhaustive, and the tenacity of purpose exhibited in its development unflagging, that praise or criticism is alike silenced. Such an one was John Napier of Merchiston, who three hundred years ago taught the world the principle and use of logarithms, bringing an immeasurable assistance to the mathematician, and marking an epoch comparable in importance with that of the introduction of our present system of notation, in which the significance of integers is defined by their position. The pure mathematician will gladly admit that Napier did a great deal more than facilitate the operations of arithmetical computation. His method was as remarkable as his result, and it is well that we should have the opportunity to review his work as a whole, not permitting the practical importance of his invention to blind us to the theoretical value of his conception, involving as it did the principle of an important mathematical function. It was the first many-valued function introduced into mathematics.

The needed opportunity was furnished by the tercentenary of the publication of the *Canon Mirificus*,* fittingly celebrated in Edinburgh in July, 1914, to which attention was drawn in these columns at that time. The date selected for the celebration was fortunately before the outbreak of hostilities, and it was possible for representative mathematicians of the different European nations to tender their kindly appreciation of one of the most remarkable minds that ever enriched mathematical science. German thought has since been distorted by passion and impotent rage, but we are inclined to regard the congratulatory expressions to the Royal Society of Edinburgh as sincere, and can remember with satisfaction that in the last Congress held before the calamitous struggle that has overtaken Europe, the whole mathematical world could meet with practical unanimity on the common ground of admiration of the great Scotch genius, who made so notable an addition to the sum of human knowledge.

The scientific programme of the Congress included: (1) A public reception, at which an address on Napier's life and work was to be given by Lord Moulton; (2) an exhibition of logarithmic and mathematical books; of all kinds of machines and apparatus which facilitate calculation; and of objects of historic interest in connection with Napier; (3) the publication of a memorial volume containing the more important addresses delivered or submitted to the Congress by the many eminent mathematicians, British and foreign, who had expressed a desire to take part in the celebration. This programme, with some minor additions, was carried out, and the memorial volume, edited by the indefatigable secretary of the commemoration, is now before us.† It is alike worthy of the man it celebrates and the occasion that calls it forth. Tributes to his memory and his worth have come from very varied quarters. Biographical details are necessarily few, for it was not the fashion in Napier's day to publish volumes of reminiscences and memoirs. Modern mathematicians are eager, however, to do justice to his memory and to illuminate what is obscure in his work. The research of experts should make us aware of how much we have accepted without question and possibly without comprehension. Very few of us have cared to fathom the processes by which Napier arrived at his conception of the logarithmic function, to examine his methods of calculation, and to trace the steps by which he arrived at a practical result. This neglect of an ancient classic may be due to the fact that Napier has left no historical references by which it is possible to follow the growth of the main idea. We who have been accustomed to approach the consideration of logarithms as exponents, and to have the difficulties removed by some previous familiarity with the symbolism of algebra, have little knowledge, or, it may be, respect, for the remarkable and fundamental method by which Napier approached the subject.

It may not be possible now to reconstruct the successive steps that Napier trod for twenty years before he reached a satisfactory goal, but the difficulties in the way apparently provoked Lord Moulton to turn the analytical skill that has been fostered by long practice in dissecting intricate and contradictory evidence to a solution of the problem. With the view not of minimising the greatness of the achievement, but of rendering it less mysterious, Lord Moulton suggested, with some plausibility, that Napier originally started with the idea of facilitating trigonometrical calculation, since he worked exclusively on sines, and apparently recognised only at a later stage of his work that similar reasoning could be applied to numbers generally with equal advantage. As he advanced in his task, Napier would perceive that if the product of numbers was to be derived, a process of continuous multiplication must be adopted, and to avoid the inconvenience of the gaps between successive numbers becoming large and unmanageable, he would be led to select a factor slightly less than unity, so that each multiplication reduced the number operated upon by only a small quantity. A further stage is indicated when he passed from the idea of arithmetical numbers to the geometrical representation of a quantity by a line, in which the effect of repeated multiplication was accurately represented by cutting off one and the same fraction of the diminished length of the line. The identity of the two processes, the multiplying by a factor little less than unity, and the cutting off of the proportional part is obvious; but the associations connected with the two operations are widely different. In Lord Moulton's view, Napier was led by this step to establish the all-important proposition that the logarithms of proportionals are "equally differing," a decisive step that brought him within sight of the third stage, in which he passed from discontinuous to continuous motion. He did not reason as Newton did at a later date in his "Fluxions;" he was satisfied with his proof, or his experience, in the case of discontinuous motion, and boldly jumped, though possibly not without some qualms of conscience, to the principle of continuous motion. And he was justified, for without troubling himself with any metaphysical subtleties, he saw that he could reach an accuracy sufficient for practical purposes, and that tables could be at once computed. His concepts evidently extended as he proceeded; but he wisely resisted the temptation to turn from his comparatively restricted task to attack another and untried scheme. He was determined to finish the useful work he proposed to himself, and he devoted some twenty years of his life to the fulfilment of his self-imposed task. Lord Moulton would impress us with the conviction that Napier did not conceive the invention in its full perfection by a heaven-born inspiration. It was the fruition of persistent and intelligent effort by a great mind, the result of gradual and continual progress. In principle his work was as complete as it was great. "We know," said the President in conclusion, "infinitely more of the nature and relations of logarithms than Napier, or any man of Napier's age could have done . . . but not all the three centuries that have elapsed have added one iota to the completeness or the scope of the two and only existing systems of logarithms as they were left by the genius of John Napier of Merchiston."

Dr. Glaisher's contribution to the collected papers is very scholarly and incisive, as might be expected from one who has interested himself in the literature of the subject, and devoted much of his leisure to the construction of mathematical tables. The *obiter dicta* are especially refreshing. He tells of the feeling of amazement, a feeling in which we have all shared according to our temperament, with which as a school-boy he first looked into a book of logarithms, and marvelled at the assistance it supplied in shortening some arithmetical processes. "The mystery, of course, passed away, but the wonder has never left me, and although in all the years since then I have been interested in and concerned with mathematical tables and logarithmic computations, I have only admired more and more the table itself, as a consummate piece of human effort, applying with singular effect mathematical principles to the general services of mankind." Dr. Glaisher returns to the subject, citing other great names that have yielded to the same fascination, and allays an uneasy conscience that accuses him of the time spent in calculating arithmetical quantities with a far greater degree of precision than could ever be required, by remembering that Gauss and Adams have fallen under the influence of the same irresistible attraction. He reminds us, too, of the influence and capacity that an adequate notation and symbolism have exercised on the extension of mathematics. The language of mathematics has become in itself an instrument of research indicating the way to further progress. Without suitable notation it would be impossible to express a differential equation, or ever to conceive of them, if complicated, much less to deal with them, and even comparatively simple algebraical quantities could not be treated in combination. This pertinent thought should lead us to a juster conception of the magnificence of the intellectual effort by which Napier compassed his work. In his time there was no convenient notation, no subtle links to aid consecutive thought—even the decimal point is his device, which he finds it necessary to explain by repeatedly translating a decimal into a vulgar fraction—his invention was accomplished by thinking power alone. In these days, and with modern notation, Napier's problem would be expressed as the value of the integral $\int \frac{dx}{x}$, for his definition gives $\frac{dx}{dt} = -x\frac{dy}{dt}$, where y is the logarithm of x. He had to carry throughout his work the cumbrous machinery and accumulated experience that underlie these few symbols, for his table of logarithms resolves itself into, and can be briefly expressed by, the determination of y for given values of x from the differential equation

$$\frac{dy}{dx} = -\frac{1}{x}.$$

Allowing that his logarithms are whole numbers, for decimals were then little known and employed, or, in other words, that his table gives the true value of the log. of a number when multiplied by ten million, his logs. in modern notation represent numbers to the base e^{-1}. The selection of this base was due to his fundamental conception of a logarithm, and it must not be supposed that Napier was insensible to the advantages connected with the base 10. He actually proposed as improvements to put zero as the log. of unity, and unity as the log. of 10. This change was loyally and effectively carried out by Briggs, to whom the convenience of modern logs. is generally attributed. But whatever acknowledgment has been made to Briggs he most thoroughly deserved, for he was not only an able and enthusiastic successor to Napier, but his services in extending the use of logarithms cannot be over-estimated.

Dr. Eugene Smith, Professor of Mathematics, Columbia University, explores the mathematical literature of the sixteenth century, seeking for evidences of familiarity with the law of exponents in those early times. The result of his inquiry is to show that though Napier may not have been led to his results through the consideration of logarithms as exponents, the relations between the arithmetical and geometrical series of numbers were fully recognised, and that consequently the fundamental laws of logarithms had been at least experimentally discovered. The relationship implied in the expression $a^m \times a^n = a^{m+n}$ was known to Archimedes, and Professor Hughes showed in various interesting ways how this fundamental principle is exhibited in the writings of early mathematicians. Stifel, writing in 1544, has been credited with the discovery of the basal laws, but he was anticipated. A prior claimant exists in Rudolff, who gave the two equations for multiplication and involution. To Stifel, however, attaches the credit that he detected the importance of negative exponents, giving as illustration the series :—

−3	−2	−1	0	1	2	3	4	5
$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	1	2	4	8	16	32

and from his time onwards, frequent comments are made by various writers, among others by Simon Jacob and the better known J. Burgi, whom some acclaimed as a precursor of Napier.

This question of priority of discovery is discussed very fully by Dr. F. Cajori, Professor of Mathematics, Colorado, but the topic is not very edifying. Nearly every scientific discovery has raised a

* The full title is "Mirifici Logarithmorum Canonis descriptio. Authore ac Inventore, Joanne Nepero, Barone Merchistonii, &c., Scoto. Edinborgi, Ex Officina Andreæ Hart. Bibliopole cd., dc., xiv."

† "Napier Tercentenary Memorial Volume." Edited by Cargill Gilston Knott. London: Longmans, Green and Co. [Price 21s. net.]

similar question, and the assertion of such claims need occasion no surprise, for scientific thought advances by steps, and it is not surprising that when the road is sufficiently prepared the same step is made simultaneously by several thinkers. Frequently the claim of prior discovery is championed, not by the writer himself, but by later commentators, seeking to acquire distinction or prompted by a mistaken patriotism. This is the case in the controversy that has centred round logarithms. Two mathematicians, Longomontanus, a Dane, and Mr. Edward Wright, the translator of the *Descriptio*, made no claim on their own behalf, but have found supporters of their supposed rights. The claim of Longomontanus can be easily dismissed. It rests on "a gossipy and obviously inaccurate tale of Anthony Wood," to the effect that one Craig, who had been in Denmark, called on Napier, and told of an invention to avoid multiplication and division in calculation by a process involving "proportionable numbers." The plan may have been based upon a table of square numbers arranged to give the quarter difference of two squares, or from the simple trigonometrical formula giving the product of the sines of two angles; but any connection with logarithms is not manifest. The claim urged on behalf of Wright is more circumstantial. In 1599 he published a "Table of Latitudes," giving numbers expressing the length of an arc of the nautical meridian. Martin, writing in the middle of the eighteenth century, proved that Wright's table may be interpreted as being a table of the logarithms of the tangents of half the complements of latitude. This is correct. But Wright had no idea of a logarithm, or of its use in arithmetic. He performed certain operations which involved the logarithmic function without knowing it.

The case of J. Burgi deserves more consideration. He did conceive a system of antilogarithms, and published a table in 1620—six years after Napier. If the date of publication is to be accepted as the determining factor, his case is at once out of court. But some evidence is produced to show that Burgi worked out his system as early as 1611. There is no reason to doubt this any more than that Napier had occupied himself with his scheme many years prior to 1614. Professor Cajori's conclusions appear to be justified, and should satisfy fair-minded critics. They are summed up thus:—(1) John Napier enjoys the all-important right of priority of publication; (2) that Jobst Burgi is entitled to the honour of independent invention; (3) that Jobst Burgi constructed his table some time between 1603 and 1611, and that Napier worked on logarithms probably as early as 1594. That a masterly and impartial dissection of the evidence was necessary is shown by the fact that within the last few years three German writers have positively attributed the invention to Burgi—a perverted view that we may hope is now settled.

Professor Gibson, in his contribution, contrasted the methods of using the tables of Napier and of Briggs, emphasising the feature that the original logarithms of the former are not precisely those now described as Napierian. As they were printed, one great inconvenience is experienced, from the circumstance that the tables are not arranged to make the logarithm of unity zero, rendering the calculation of products and powers an unnecessarily complicated process. Also the logarithms are not adapted to the denary scale of numbers; hence the multiplication or division by 10 requires the addition or subtraction of an inconvenient number. The main value of the paper consists in the historic review of the circumstances attending the introduction of the Briggsean form. The Glasgow professor has gone to original sources for his information, has swept away the misleading repetitions that prejudice or tradition has sanctioned, and has demonstrated the insecurity of following the beaten path that mathematical historians, like Hutton, have prepared for those incapable or unwilling to dig deeply below the surface of accepted convention. The result is to make both Napier and Briggs appear as complementing each other's work. There is no question of master and pupil, of superior or inferior; each is a master in his own work, and each occupies a monumental position.

Napier's mathematical work other than that on logarithms is adequately and sympathetically treated by Professor Steggall, who describes the posthumous work *De Arte Logistica*, and Dr. Somerville, who presented a paper on Napier's Rules, and trigonometrically equivalent polygons. In the former it is established that Napier was the first to use imaginary roots of equations, thus displacing Girard, who is usually credited with this advance. In the latter paper the "Rules" are lifted above the level of mere mnemonics, and restored to the position of theorems, the light in which Napier originally regarded them. Dr. Somerville exhibits their true character in relation to the star pentagon with five right angles.

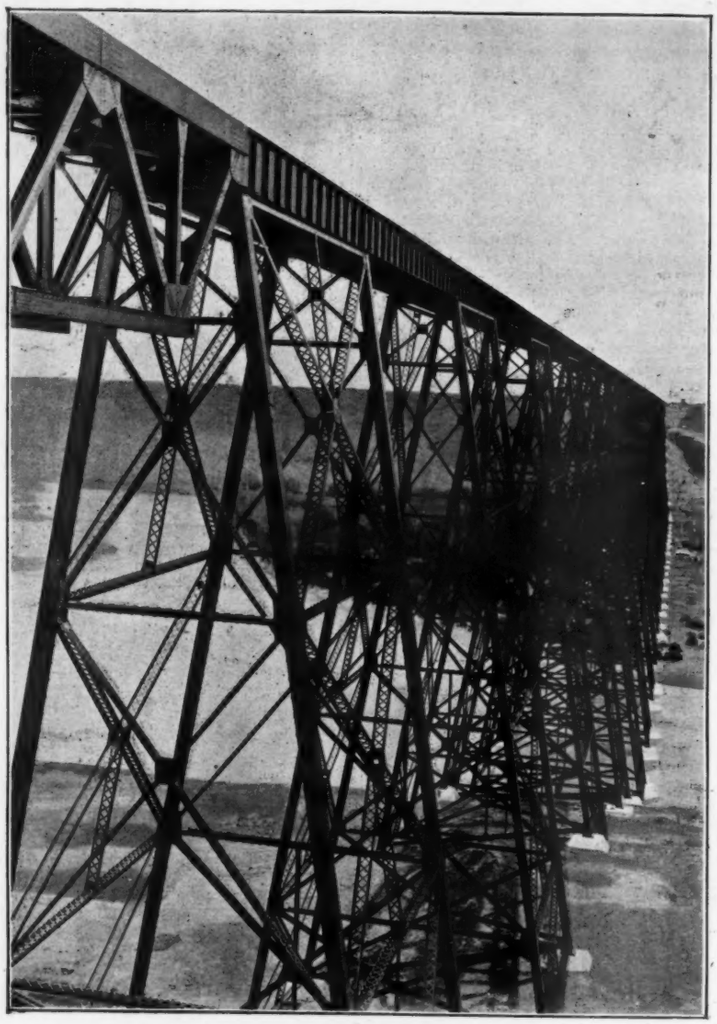
In addition to illustrating the actual work of Napier, several papers were presented on the modern method of computing logarithms, ensuring greater accuracy and a wider application. Such references are fittingly included in the celebration as developing and perfecting the work whose origin the Congress was called to commemorate, but being of a different character from the historical portion, need not be described here. Among these papers is one by Professor Andoyer, of Paris, who has successfully produced a new and complete table to 14 decimals of the logarithms of the trigonometrical functions, and contemplates extending the work to include numbers, maintaining a similar accuracy. Another paper by the editor, Professor G. C. Knott, describes the work of Dr. Sang, who calculated, but did not publish, the logs. to 15 decimal places of numbers up to 370,000, with a table of sines possessing equal accuracy for arcs of the quadrant differing by one minute, centesimal division. Still further removed from the main purpose, though adding to the general interest of the volume, are papers by Dr. Hutchinson on "The Graphical Treatment of some Crystallographic Problems," and one on "Life Probabilities," by M. Albert Quiquet, which may be regarded as a fitting contribution on the part of the actuarial profession, than whom none has benefited more from Napier's conception.

We are obliged to pass over unmentioned many short papers in which the respective authors have sought to offer a tribute to the memory of a great mathematician, but grateful acknowledgment must be made of the care and labour that Professor Sampson has bestowed on the preparation of an annotated catalogue and admirable description of the rare exhibits that constituted so prominent a feature of the celebration. Also it must not be forgotten that Napier necessarily exhibited other activities than those of a diligent computer. He played his part as a worthy citizen and laboured strenuously whither he thought duty called him. Though biographical materials are scanty, Professor Hume Brown and Mr. G. Smith, the headmaster of Merchiston Castle School, contribute papers on the life and environment of Napier. The one reconstructs the social and religious life of the end of the sixteenth century, and shows us the man

THE LETHBRIDGE VIADUCT, SOUTH ALBERTA, CANADA.

MR. C. N. MONSARRAT, M. CAN. SOC. C.E., ENGINEER.

(*For Description, see opposite Page.*)



GERMAN PORTABLE WIRELESS-TELEGRAPH APPARATUS.

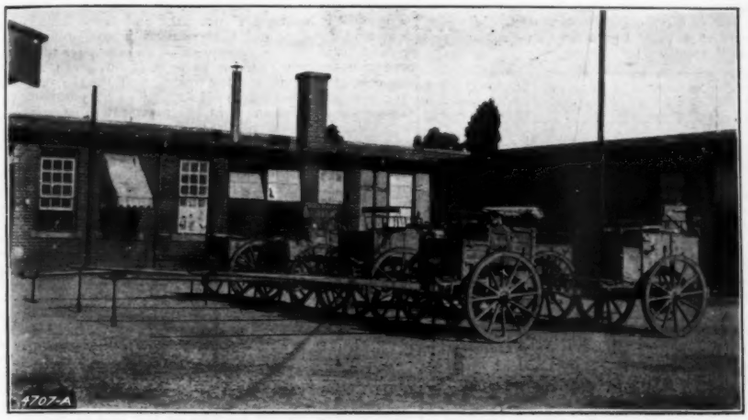


FIG. 1.

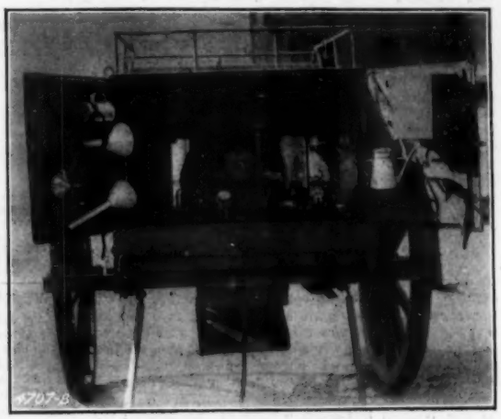


FIG. 2.

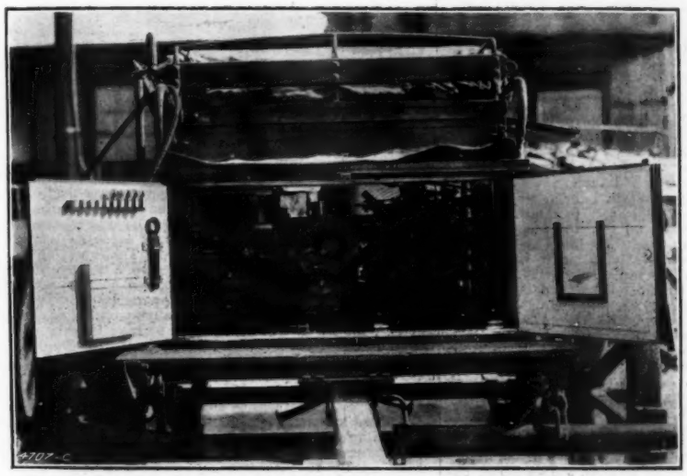


FIG. 3.

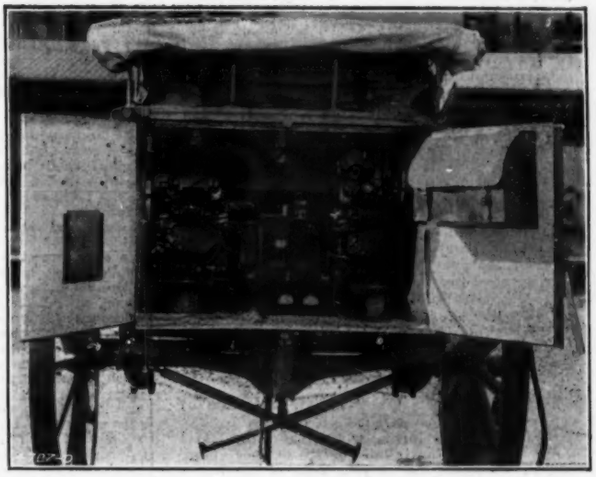


FIG. 4.

sometimes pleading in the law courts in defence of his rights, at other times wrestling with theological difficulties which found expression in the controversial volume "A Plaine Discovery of the whole Revelation of S. John." But, in truth, we know very little of his temperament and character. We have "no clear glimpse of him as son or husband, or father, or as a friend or as an enemy. . . . He here bore his testimony to the truth which he held to be of the highest concern for his countrymen and for the world at large." The other shows us the house in which Napier lived when in Edinburgh—a substantial building that appears to have come into the Napier family about 1438, that, and after various changes of possession, has for nearly a century been utilised as a high-class school.

We beg to offer our hearty congratulations to Professor Knott and to all who have been concerned in producing this handsome volume, commemorating an epoch in the history of mathematics, and destined to preserve the memory of one of Scotland's greatest sons.

THE LETHBRIDGE VIADUCT.

THE Lethbridge Viaduct on the Crow's Nest branch of the Canadian Pacific Railway, in Southern Alberta, illustrated on the opposite page, is, taking the two dimensions together, the longest and highest bridge in the world. Its length is 1 mile 47 ft., and its height 307 ft. from water-level. The bridge was designed by Mr. C. N. Monsarrat, now chairman of the Board of Engineers of the New Quebec Bridge. It is a steel viaduct, consisting of 44 plate-girder spans 67 ft. long, 22 plate-girder spans 99 ft. long, and one riveted-deck lattice span 167 ft. long, the whole carried on 33 rigidly braced riveted steel towers. The substructure consists of concrete piles, supporting concrete pedestals, the length of the piles varying from 12 ft. to 20 ft. The towers were designed with a batter of 1 to 6, which, with the girders of the spans spaced at 16-ft. centres, gives ample spread at the base.

The material used in the bridge was mild open-hearth steel, of 60,000 lb. ultimate strength. The live load provided for consisted of two "Consolidated" engines, coupled together, each weighing 337,000 lb., followed by a uniform train-load of 4000 lb. to the lineal foot. The effect of impact and vibration was provided for by the well-known Schneider formula. For the portion of the structure over 125 ft. high, 100-ft. intermediate spans were decided upon, and because of the very high prevailing winds, spans of the through, instead of the deck-girder, type were used.

Owing to the very irregular banks, the fixing of the exact length of the bridge presented a difficulty. An unsupported tape was considered of little value owing to the wind, and it was not practicable to use a supported tape, so a wooden rod was chosen.

The bridge required some 645 car-loads of structural steel and 1000 cars to haul the other material in the structure. The quantities are as follow :—

Dry excavation	18,110	cub. yards
Wet excavation	4,870	"
Concrete	17,090	"
Concrete piling	1,676	piles
Riprap	339	cub. yards
Steel...	12,300	tons
Field rivets	328,000	

The traveller for the erection of this bridge was a very ponderous machine. The clearance under the deck was sufficient to permit the passage under it of loaded flat cars. To provide for the safety of the workmen two assembling-bridges were used, and a system of telephones installed, with a head-piece for each engine operator.

GERMAN PORTABLE WIRELESS-TELEGRAPH SETS.

IN addition to the permanent wireless stations at Ludertzbucht, Swakopmund, and Windhuk, in South-West Africa, the German forces in that colony were provided with a number of portable sets on the "Telefunken" system, and those which were not completely destroyed were handed over to the Union forces at the termination of hostilities. Photographs of two such stations, which at the time of the surrender were erected respectively at Karab and Zesfontein, a distance of 250 miles apart, are reproduced above. The first of the photographs, all of which were taken by Mr. M. Edward, of Johannesburg, shows the two sets awaiting minor repairs at the Johannesburg Telephone Exchange. As will be seen, the apparatus for each set is carried on two four-wheeled vehicles, one of which contains the sending and receiving apparatus and the generating plant, while the other carries the aerials, spare gear, and supplies. Fig. 2 shows the generating plant, which, it will be seen, is contained in a pressed-steel dust-tight case. The plant comprises a water-cooled petrol-engine running normally at 1500 revolutions per minute, and giving from 5 to 6 horse-power at that speed, coupled to an alternator giving 35 amperes at 85 volts at a frequency of 500 cycles per second; the engine also drives a small continuous-current exciting dynamo giving 8 amperes at 50 volts. The sending apparatus is shown in Fig. 3, the multiple spark-gap being

visible on the left, and the inductance on the right; the latter is supplied with tappings giving wave-lengths ranging from 545 to 1200 metres. The backs of the ammeter and voltmeter for the primary circuit can be seen in the top left-hand corner of Fig. 4. This illustration shows the receiving apparatus, which is carried at the other end of the same vehicle as the sending apparatus; two complete sets, mounted on the left-hand and right-hand sides of the vehicle, are provided. The receiver consists of two coils, one of which is fixed and is connected in series with the aerial, when receiving, by means of the "send or receive" switch clearly visible at the top of each set; the other coil is hinged and can be moved so as to vary the coupling. These two coils, which are placed near the centre of each set, are provided with plug-and-socket tappings and with a multiple switch, both of which are visible in the illustration. These are used, together with the variable condenser mounted in front of each set, for tuning and enable messages in wave-lengths ranging from 100 to 3000 metres to be picked up; the small two-way switch, visible on the top right-hand corner of each set, is used for changing over from short wave-lengths to long wave-lengths, and *vice versâ*. Two crystal detectors are provided for each set, and these are mounted on the top left-hand corner of the base-boards. The telephone receivers, which fit over the operator's head when a message is being taken, are connected to the bottom left-hand corner of the board; they can be distinguished in the illustration lying near the variable condensers. Just behind the receiver on the left-hand side the handle of the sending-key can be seen. Between the two receiving sets is a box containing the wave-meter, and above the right-hand set is a hot-wire ammeter for measuring the current in the aerial. Connection to the latter is made by the insulated terminal seen to the left of the ammeter, and the terminal still further to the left connects the aerial to earth. The leather bag attached to the door on the right-hand side contains stationery for use in connection with the transmission and reception of messages.

From the above brief description it will be seen that the sets, which were made by the Gesellschaft für Drahtlose Telegraphie m.b.H., of Berlin, are exceptionally complete and serviceable. Their range would be about 100 miles by day and about 150 miles by night over ordinary country with the steel masts, 25 m. (82 ft.) high, usually employed; the range could, however, be greatly increased by using higher collapsible steel masts, or by placing the apparatus in favourable situations. The total weight of the vehicle carrying the sending and receiving apparatus and the generating plant is about 1½ tons, and that of the other vehicle, which carries the mast, &c., is slightly more than 1 ton; both are drawn by four horses.

THE QUESTION OF SIZE OF MILITARY AEROPLANES.

TO THE EDITOR OF ENGINEERING.

SIR,—The vital importance of the subject raised by Mr. F. W. Lanchester in your issue of the 3rd inst. (page 212 *ante*), and the general necessity for encouraging progress in the science of aeronautics, are my justification for asking permission for the publication of observations on the views propounded by Mr. Lanchester. The military demand is for machines to carry a greater load and to have a wider radius of action. Mr. Lanchester seeks to impose limitations in respect of these requirements, on the principle that the weight of the machine light increases proportionately with its size or lifting power. Were this dictum accepted, there would practically be an end to progress in this direction.

I propose to consider only one phase of the subject, because he has devoted most of his article to it—namely, the relation of the weight to the area of the aerofoil. The question of the aerofoil area in relation to weight of machine and to the area of the ground available for alighting need not be raised, although it will be recognised, even by the tyro, that this is not such an important factor in the case of hydroplanes or seaplanes. But I join issue with Mr. Lanchester in his view that weight of aerofoil must increase in proportion to its area or to the size, and therefore the lifting power, of the machine.

The strength of a rib in a small or scouting machine is approximately double the strength required, on account of handling and other practical considerations. Hence, if the dimensions of a machine be doubled, the dimensions of the rib need not be doubled—*i.e.*, the weight of the rib need not be increased eight times. Further, it is not practicable to make very small struts hollow, as the thickness of the walls must be such as to allow them to be handled. Again, in the case of spars, if the size were increased sufficiently, it would be possible to shape them correctly to take shear, bending moment, and compression at each point, whereas it would not be feasible to do this in the same degree with a small spar, as the thinness of the walls permissible theoretically would render them too fragile to be handled. The same reasoning might be applied to the leading and trailing edges of the wings. Hence, if the size of a machine were doubled, the weight on the wings would not be increased eight times, as the only portion that would vary as the cube would be the cables.

The chief requirements in making wings of a small size are that they shall be strong enough—

(*a*) for men to hold the machine back by them when the engine is running,

(*b*) for men to handle them when erecting the machine without undue damage, and

(*c*) to give apparent stiffness to the spars.

All these demands for extra strength and weight disappear as the size of the machine is increased.

From my own experience I give the following analysis of three standard machines:—

Machine.	Total Weight Relative to A.	Maximum Speed Relative to A.	Percentage of Loaded Weight.			Weight of Wings per Cent. of Loaded Weight.	Factor of Safety (Minimum).	Loading, Lbs. per Sq. Ft. of Wings.
			Machine Alone.	Military Load.	Fuel for same Radius of Action.			
A Tractor	—	—	60	20	20	18	6	6.5
B Pusher	45 p.c. greater	30 p.c. less	59.5	21	19.5	19.5	6	6.0
C Tractor	250 p.c. greater	15 p.c. less	63.5	20	13.5	20	6	6.4

NOTE.—The fuel in each case is for the same number of miles.

Mr. Lanchester has dealt with the question also in *Land and Water* of February 10 and 17 last. In dealing with the theory of the three-gun battleplane attacked by three Fokkers (one-man, one-gun machines) he seeks to prove that the multi-armed biplane is certain of defeat, chiefly owing to its larger vulnerable surfaces. I can grant him all this if it is taken that the biplane is unduly slow and its armament fixed. No designer, official or otherwise, would contemplate such a machine, but rather one with a good all-round field of fire, so arranged as to enable at least two of its three guns to bear on hostile machines when attacking.

To go a step further, I am also of the opinion that a large biplane would probably have at least one heavy gun of long range, capable of disabling any aeroplane with one direct hit; it would be of approximately equal speed to the Fokkers, and the pilot should be given credit for sufficient intelligence and skill to manœuvre his biplane to the best advantage, so as to make the most of his superior range.

Mr. Lanchester further seeks to prove that large machines are inferior to small ones. Perhaps they are in some respects, on the same basis that a super-Dreadnought would be inferior to a torpedo-boat destroyer for destroyer work. Without going into the matter academically, I think one can only refer Mr. Lanchester to certain machines now flying most efficiently (including French, Russian, and German products) which in practice refute his argument forthwith; and, while on this subject, I can only suggest that before attempting to educate the public to ask for small fast machines, suitable only for entirely local work, he should enlarge and broaden his vision, and, looking beyond the purlieus of committee rooms, see and realise what is being done in practice.

Perhaps the most illuminative commentary on Mr. Lanchester's attitude would be a quotation from Sir David Henderson's preface to Mr. Lanchester's own recently published book, "Aircraft in Warfare." I think it gives official recognition of the danger of making restrictive assertions on a branch of science so vast, and at present in such a state of evolution, as is aviation:—

"The subject of 'Aircraft in Warfare,' with which Mr. Lanchester deals, is, and for some time will be, highly controversial. In each of its aspects, the scientific, the military, and the material or manufacturing, it is still in the stage of experiment or speculation. The results obtained cannot always be made available for the general public, and those which are available have usually been set forth in terms so technical, alike in a scientific or a military sense, as to be somewhat difficult for the general reader to understand. Very little trustworthy information therefore has been disseminated. . . ."

In his article in ENGINEERING, on March 3, Mr. Lanchester seems over anxious to show that the present situation exactly corresponds with predictions in his book published in 1908. This might be due to prescience on his part or to lack of progress. It can never be a subject of disparagement to a writer, however, if progress has been greater than he anticipated, and the fact that other Powers have advanced beyond the stage prescribed by Mr. Lanchester in his early works in no sense detracts from the service he has rendered to aviation; on the other hand, it should be a source of stimulus to those responsible for the new arm of our service. In Mr. Lanchester's writings at the present time, both in ENGINEERING and in other periodicals, there is a suspicion that he is assuming the *rôle* of apologist for the Royal Aircraft Factory. While claiming that the machines designed in the Government factory have a reliable safety factor, he says:—

"The factors of safety used as the present time by aeronautical constructors differ widely; in my James Forrest Lecture it is given that the factor of safety varies from 3 in certain machines (which shall be nameless) to as high as 7 or 8 in the case of certain of the machines constructed at the Royal Aircraft Factory. The recommendation of the Advisory Committee for Aeronautics, formulated after duly considering the conditions with which military aeroplanes have to comply, is that the factor should not be less than 5 or 6. Now with this great variation of nearly 3 to 1 in existing practice in the matter of wing strength, it is necessary to be careful in comparing different designs of machine, for it is evident that in some cases the petrol capacity might be nearly doubled merely by cutting down the weight of wing structure, without going outside the limits of existing practice."

This is a misleading statement, and is unjust to British designers and constructors of aircraft. It ought not to be accepted by the British people as proof that the progress of aviation in this country is solely due to the foresight, skill, and success of the Royal Aircraft Factory. I do not propose to enter into the question of the relative credit due to the Government factory; but I contend that the maximum progress has not been achieved in this country. It has been shown time and again that in all scientific development Government departments owe a great debt to private enterprise, alike in respect to design and manufacture. This is as true, if not more true, in the case of aircraft, and the tendency of the Government to ignore the great volume of scientific ability outside the Government department in the matter of initiative and enterprise in design, results in the air service of the Army and Navy being greatly handicapped. The advances in the past in all forms of offensive and defensive weapons have been largely due to the full utilisation of private resource, and not until the Government applies this lesson to aeronautics will our present unsatisfactory position be modified, and Great Britain brought into equality with our Allies, and into superiority against our foes. On this point I entirely support the views in your editorial article in the issue of the 17th inst. (page 262 *ante*). Matters are still largely, as you say, in an experimental stage, and therefore centralisation and standardisation must prove a serious drawback to progress. Whether we have a Minister for Air or not, it is incumbent upon the authorities to seek the co-operation of the firms who have specialised in the design and manufacture of aircraft, and I can recommend no better way of advance than to give to responsible manufacturers a free hand in the production of the best air machine which they can conceive, on the same principle as was adopted in the past in respect of torpedo-boat destroyers, guns, and mountings, and other munitions. I believe the result would be as satisfactory in respect of aeronautics as in those other items of equipment of the Navy and Army.

I am, Sir, yours truly,

AEROPLANE DESIGNER-CONSTRUCTOR.

March 29, 1916.

"ON THE WHIRLING SPEEDS OF LOADED SHAFTS."

TO THE EDITOR OF ENGINEERING.

SIR,—The important contribution by Mr. W. Kerr, "On the Whirling Speeds of Loaded Shafts," in ENGINEERING for February 18 and March 3, 10, and 17, contains numerous references to the work of Professor Dunkerley and myself on the subject. In Dunkerley's calculations and my own* the simplifications made to bring the problems treated within the range of ordinary mathematics were in many cases so heroic that it is satisfactory to find that calculated results agree so closely with experiment as they seem to do. The extension at which Mr. Kerr has arrived indicates a tendency to whirl at a lower speed than that given by the earlier work. His own experiments were apparently confined to a 250-kw. impulse turbine and a 3-horse-power De Laval turbine, the latter of which seems to have been hardly amenable to the exact numerical application of Dunkerley's formulæ. Under these circumstances I would suggest the desirability that a result of such apparent practical importance as Mr. Kerr's should be put to a more varied experimental test by engineers who have turbines of different kinds at their disposal.

Mr. Kerr's references to my own work are so flattering that I hesitate to call attention to one point in which he seems hardly to interpret my views correctly. This applies to my attitude towards Professor Dunkerley's working formula,

$$N^{-2} = N_1^{-2} + N_2^{-2},$$

or, in my notation,

$$\omega^{-2} = \omega_1^{-2} + \omega_2^{-2},$$

where ω denotes a critical angular velocity.

A prelimary point which must be grasped, if the situation is to be properly understood, is that the method I employed, which is also employed in some of Mr. Kerr's work, is one developed in that valuable treatise Lord Rayleigh's "Theory of Sound," which is subject to a qualification carefully explained by Lord Rayleigh himself. It is intended to be used in cases where the determination of the precise way in which a body vibrates has proved too much for the resources of the striot mathematical theory. Even in the simpler statical problems presented by the bending of a loaded shaft, the results derived from the ordinary elementary theory of Euler and Bernoulli are not exact—a fact which "practical" men seem occasionally to forget. Lord Rayleigh showed how *approximate* results for the frequency of vibration can be found by assigning hypothetical forms to the type of vibration; but the frequency thus deduced will not be exactly correct unless the assumed type is exactly the true one. We know, indeed, from a general theorem established by Lord Rayleigh, that the frequency thus found cannot be too low; but we cannot say by exactly how much it exceeds the true frequency, unless we happen to know the exact mathematical solution. The value of the method lies in this—that we have theoretical reasons for believing that even a large difference between the assumed type of vibration and the true one will introduce but a small error into the calculated frequency; and this view has been confirmed in a variety of cases in which the exact mathematical solution is known. In the cases in question the assumption of the statical type of displacement given by the ordinary Euler-Bernoulli theory has usually led to an error well under 1 per cent. of the true frequency.

The preceding remarks will explain that it is difficult to prove to demonstration by the vibration method that the critical speed deduced in a particular case by means

* *Philosophical Magazine*, May, 1904, page 504.

of Dunkerley's formula is in error, unless this critical speed is *greater* than that given by the vibrational method.

Mr. Kerr (page 246) seems to misunderstand the attitude adopted to Dunkerley's formula near the end of my paper in my §44. He seems to think I aimed at supporting the formula, and says of what I did "But this takes us no further than Dunkerley has already done." What I really did do was to show that in a certain limiting case—whose ideal nature I carefully pointed out—Dunkerley's formula was mathematically exact. This was, as a matter of fact, a distinct addition to what Dunkerley had done, because he simply assumed the formula as an empirical one. But I made this remark, not to support Dunkerley's formula as mathematically exact in practical cases, but only as indicative of my desire to be strictly fair and say what could be said for it. What I actually thought of it is very clearly stated in my page 505, "Dunkerley's method of arriving at his working equation—which he characterises himself as 'empirical'—is not convincing mathematically. In fact, the result does not appear to be in general strictly true; and there seems nothing in Dunkerley's work which serves to bring out the limitations."

Finally, in my §45, the paragraph immediately following that quoted by Mr. Kerr, I carried through a special investigation, having the same object as Mr. Kerr's, pages 247 and 248, respecting which I said: "The following investigation would seem to show that the result—*i.e.*, Dunkerley's formula—is not in general strictly true, though it may be, and not improbably often is, a close approximation to the truth." The case I took is in some respects more general than Mr. Kerr's, and, in fact, includes his Case I. I supposed a massless shaft of length l, supported at its ends A and B, carrying a mass M_1 at C (A C = a), and a second mass M_2 at D (C D = c, D B = b), the effect of the moment of inertia of either mass being neglected. Denoting the critical angular velocity by ω, I found

$$\omega^{-2} = \omega_1^{-2} + \omega_2^{-2} - R \quad . \quad . \quad (1)$$

$$R = M_1 M_2 (M_1 + M_2)\, a^2 b^2 c^2 (1\,a\,b + 4\,a\,c + 4\,b\,c + 3\,c^2) \div 12\,E\,I\,l \left\{ M_1^2 a^2 (b + c)^2 + M_2^2 b^2 (a + c)^2 + M_1 M_2 a\, b\, (2\,a\,b + 2\,a\,c + 2\,b\,c + c^2) \right\} \quad (2)$$

Here ω_1 and ω_2 are the critical angular velocities for the shaft when loaded with M_1 alone, and with M_2 alone. E is Young's modulus, and I the moment of inertia of the cross-section of the shaft about a diameter. To agree with Dunkerley's formula, R should vanish. Pointing this out, I added: "It is, however, obvious that R is positive for all values of M_2/M_1, and for all values of a, b, and c. It vanishes, it is true, when c vanishes, but the two loads then coincide in position. As R is positive, the application of Dunkerley's hypothesis gives a larger value for ω^{-2}, and so a smaller value for ω^2, than does (1)." I explained that this was not immediately conclusive against Dunkerley's formula, for the reasons stated above in connection with Rayleigh's method, but that an unfavourable conclusion as to the absolute accuracy of the formula naturally followed from the fact that R was not a very small quantity except for special values of a, b, or c. In the case I selected for numerical treatment, $M_2 = M_1$, and $a = b = c$, I showed that

$$\omega^{-2} = (\omega_1^{-2} + \omega_2^{-2})\,(1 - \tfrac{1}{16}),$$

indicating a departure of about 6 per cent. from Dunkerley's result for ω_1^2, or about 3 per cent. from his value for ω, a result closely similar to the differences obtained by Mr. Kerr in the cases he treated.

The general expression (2) for R is somewhat cumbrous, but there is no difficulty in deriving numerical results from it for any specified values of M_1, M_2, a, b, c, &c.

In the case of symmetry, when $M_2 = M_1$, $b = a$, and $\omega_2 = \omega_1$, let ω_v and ω_r represent the critical angular velocities given respectively by Dunkerley's formula and the vibration method. After a little algebraic manipulation of the expression for R we find

$$\frac{1}{\omega_r^2} = \frac{2}{\omega_1^2}\left\{1 - \tfrac{1}{4}\left(\frac{l - 2a}{l - a}\right)^2\right\},$$

while

$$\frac{1}{\omega_v^2} = \frac{2}{\omega_1^2}.$$

Thence

$$\omega_v = \omega_r \left\{1 - \tfrac{1}{4}\left(\frac{l - 2a}{l - a}\right)^2\right\}^{\frac{1}{2}}.$$

Thus ω_v/ω_r varies from 1.00 when $a = l/2$ (*i.e.*, when the two masses combine into one at the centre of the shaft) to 0.87, when a/l is vanishingly small (*i.e.*, when the loads are close up to their respective ends of the shafts). The latter extreme case is hardly a practical one, nor should we expect any very accurate result from the vibration method under such circumstances. But a reasonably practical case is obtained by taking $a = l/12$—*i.e.*, by supposing the distance apart of the two loads to be ten times the distance of either from the nearer end of the shaft. In this case we find—

$$\omega_v / \omega_r = 0.89,$$

implying a difference of 11 per cent. between the result given by Dunkerley's formula and that given by the vibration method.

The difference here is considerably greater than in the case $a = b = c$ selected in my original paper, or in the three cases treated by Mr. Kerr, and it is not improbable that even greater differences might present themselves in some cases of non-symmetrical loading.

There is no real difficulty, except in the length of the resulting expressions, in applying the vibration method to more complicated systems of loading than that considered above.

Yours truly,

C. CHREE, Sc.D., F.R.S.

75, Church-road, Richmond, Surrey.

TO THE EDITOR OF ENGINEERING.

SIR,—In your recent numbers I have read with much interest the articles by Mr. Kerr, "On the Whirling Speeds of Loaded Shafts," and more particularly that part that relates to the 250-kw. turbine, and his theoretical investigation of the apparent discrepancy between practice and accepted theory.

The subject is one of considerable practical importance, and this account of Mr. Kerr's experimental work is a very desirable addition to the literature of whirling speeds, more especially as his investigations have been carried out on turbine rotors of fair size.

I write to call attention to an error in his theoretical investigation on pages 224 and 225. Mr. Kerr makes the fundamental assumption that a shaft supported horizontally rotates around the straight line joining the centres of the bearings, and not around the gravitationally deflected position of its axis. This is erroneous, as I will endeavour to explain. Imagine a heavy shaft freely supported at its extremities. Its axis will assume a deflected form, and for the sake of clearness let us imagine the deflection to be large—*i.e.*, a heavily loaded shaft of small diameter. If a point on the axis receive a very slight transverse displacement and be released, it will oscillate about the gravitationally deflected position of the axis, and ultimately come to rest again in that position. It will not, when slightly disturbed, proceed to straighten itself into a horizontal right line, and oscillate about the unstrained position as though gravity had ceased to act.

Next suppose the shaft to rotate, at first very slowly. The load at any point will rotate about the deflected position of the axis. To assume that the shaft will rotate about the unstrained position or line joining the bearings amounts to assuming that gravity will not act on the shaft because it rotates. If the load be out of balance the centre of mass does not coincide with the axis of the shaft, and the centrifugal force thus

Fig. 1.

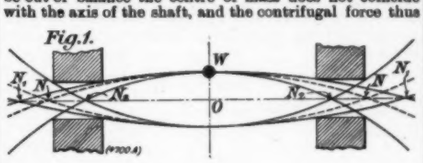
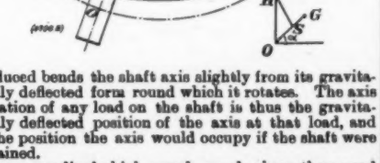


Fig. 11. AMENDED.



introduced bends the shaft axis slightly from its gravitationally deflected form round which it rotates. The axis of rotation of any load on the shaft is thus the gravitationally deflected position of the axis at that load, and not the position the axis would occupy if the shaft were unstrained.

At an exceedingly high speed—much above those used in practice—the shaft axis will tend to straighten from the deflected form; but with that we are not here concerned. Thus we see that rotation takes place about the gravitationally deflected axis of the shaft, and not about the straight line joining the centres of the bearings or position the shaft would occupy if unstrained—*i.e.*, if gravity were annulled. In short, the force of gravity and the elastic forces consequent on the gravitational deflection of the shaft are in equilibrium, and the oscillations and displacements due to centrifugal action take place about this equilibrium position.

Now Mr. Kerr's contention on page 224, column 3, is based on this incorrect assumption of rotation about the unstrained position of the axis, and later, on page 225, where the mathematical investigation is given, the same assumption underlies. There the potential energy due to gravity is included, but the corresponding elastic energy caused thereby is omitted.

Fig. 11, page 225, should be amended as shown in Fig. 11, above.

H is a point on the line joining the bearing centres, or the position of the axis of the shaft when unstrained. O is the centre of rotation of the wheel. S is the centre of the displaced shaft, and G the centre of mass of the wheel, as in the paper.

Write H S = v; O H = q.

The value of the kinetic energy T is as given in the paper; but in the expression for the elastic energy, m is to be replaced by H S, or v, as this is the elastic deformation.

Thus $S = \dfrac{3\,E\,I\,(a + b)\,r^2}{2\,a^2\,b^2}$ replaces equation (*g*). Now $v^2 = q^2 + m^2 - 2\,q\,m \sin\alpha$, by geometry, and the static deflection of the shaft due to the load W is $q = \dfrac{W\,a^2\,b^2}{3\,E\,I\,(a + b)}$.

The value of $\dfrac{\delta V}{\delta v}$ thus becomes $\dfrac{\delta V}{\delta m} = \dfrac{3\,E\,I\,(a + b)}{a^2\,b^2}\,m$,

the term in $\sin\alpha$ in equation (0) disappearing.

The final solution (equation (*r*)) then becomes $m = F \cos\sqrt{A - B\,\omega^2}\,.\,t + E \sin\sqrt{A - B\,\omega^2}\,.\,t + \dfrac{C\,\omega^2\,\varepsilon}{A - B\,\omega^2}$.

Thus the second solution given by Mr. Kerr (page 225, bottom of column 3) does not exist, and the theoretical foundation for his new critical speed disappears.

While I have thus shown the error in the theoretical deduction of the new speed, one must face the practical fact that the actual whirling speed as measured differs considerably from that calculated in the ordinary way.

The explanation I would offer—so far as I am able to judge from the data in the paper—is that there is a slight looseness in the bearings, especially towards their inner faces.

At the first whirling speed, as is well known, the shaft vibrates in a single loop with nodes at the bearings; at the second whirling speed in two loops, and so on. The actual position of the nodes within the bearings depends on the looseness or play possible. Thus if the bearings be loose, vibration in one loop is possible with the nodes away from the bearing centres. The value of the critical speed for such vibration is given by the ordinary theory, in which, however, l represents the distance between the nodes. As the speed is increased the corresponding inter-nodal distance, at which critical vibration can occur, becomes less; and if the play in the bearing permits it, vibration of sufficient amplitude to transmit serious alternating loads to the bearings may be set up. Thus with very slight play or looseness, or with give or yielding in the bearings, vibrations of a serious kind may occur for a short range of inter-nodal distances, and corresponding range of speeds. In fact the range of speed observed in the experiments as being critical may thus be explained by play or give at the bearings.

The fact that vibration occurs from 2450 to 2600, and even up to 3000, revolutions per minute thus indicates looseness or play, which, it may be seen, need only be of very small amount indeed to permit an amplitude of vibration sufficient to cause serious stress on the bearings due to centrifugal forces. I should note, however, that if the shaft be slightly out of balance, vibrations of a serious magnitude may be expected to occur over a range of speeds at the critical period, even for definite bearing conditions. It is therefore reasonable to suppose that vibration may occur in which the nodes are farther apart than the centres of the bearings. If the inner ends of the bearings are loose and the outer faces a close fit, the virtual centres of the bearings, so far as vibration is concerned, may be practically at the outer ends; for these may be nodes of the vibration.

Taking the calculated value of the first whirling speed for the turbine-rotor as 3300, the nodes being assumed at the centres of the bearings, then approximately the value of l, for which 2500 revolutions per minute would be critical, is 56½ in. But the journals are of much smaller diameter (2½ in.) than the main part of the shaft, so that the mean flexural rigidity of the greater length of the shaft is less. If for the length affected by the vibration we suppose an average diameter of 4½ in., instead of 4½ in., as taken by Mr. Kerr for the shorter length of shaft, we find that a length between nodes of 52½ in. will correspond on the ordinary theory to a critical speed of 2500 revolutions per minute—*i.e.*, the virtual centre of the bearing would be towards the outer faces.

Mr. Kerr does not say whether he experimentally measured the value of the flexural rigidity of the loaded shaft. It would be of interest to know its actual value. This can, of course, be done by supporting the rotor on straight ways, and measuring the additional deflection at the centre of the shaft caused by suspending a known weight at its middle point. The ways should be placed at different distances apart, say, from 42 in. to 60 in., and the corresponding flexural rigidities determined.

I have drawn Fig. 1 to make the matter clearer. It shows in plan the shaft axis as deflected by centrifugal force. The bearings are shown diagrammatically only with very great looseness, the deflection of the shaft also being exaggerated.

The centrifugal force on the shaft being $\dfrac{W}{g}\,\omega^2\,r$, where r = O W, it will be noticed that alternating loads of serious amount will be transmitted to the bearings, provided r is sufficiently great. The figure shows that such value of O W is permitted by the bearings, provided the nodes of the single loop lie between N_1 and N_2. In fact, the bearing does not definitely determine the length between nodes, and we have critical vibrations (of serious amplitude) possible corresponding to the different values of l from $N_1 N_1$ to $N_2 N_2$. Thus we have a range of critical speeds. In practice, such range of critical speeds is usually observed, as also in Mr. Kerr's experiments. On the other hand, if the bearing be very close fitting and not spherically seated or capable of adjusting itself to changes of deflection, it may even constrain the nodes to fall within the distance between the bearings, as in the case of a "built-in" beam.

The magnitude of the central displacement of ¼ ton rotor required to produce alternating loads of, say, ¼ ton on each bearing at 2500 revolutions, and the distance between bearings of 47 in., is about 0·005 in. A looseness in the bearings of about 0.001 in. would permit this. Clearances between journal and bearing of more than this are usual (*cp.* British Standard Tolerances and Allowances for Running Fits). Mr. Kerr, indeed, refers at some length in his paper to the slackness of fit of bearing II. of the 3-horse-power turbine.

In conclusion, although I find myself in disagreement with his main contention, I think Mr. Kerr has done a useful service in giving the results of his investigations so fully.

I am, Sir, yours very truly,

Dublin, March 16, 1916. H. H. JEFFCOTT.

P.S.—Since writing the foregoing, your number for March 17 has appeared. I need scarcely point out that the alternative method of solution in Appendix A, page

246, is based on the same assumption, and if modified in accordance with the amendments indicated above, will, of course, lead to the same amended equation for m.

I notice on page 251 that Mr. Henderson's experience appears to indicate the non-existence of the "new" critical speed, so that practically and theoretically there does not seem to be justification for such new critical condition.

H. H. J.

TO THE EDITOR OF ENGINEERING.

SIR,—I have read Professor Morley's letter on the above article, which you published in your last issue, and I agree with his remark that further experimental information on this subject is desirable, if it can be readily obtained.

In my opinion the disturbance under discussion could hardly show itself with rotors that are exceptionally well balanced. These would rotate with the elastic curve of the shaft concave upwards, the "whip" being rapidly generated close to the usual whirling speed, and almost certainly above 70 per cent. of that value. But when the out-of-balance was material—and at what figure this would become so would be difficult to define—the whipping action might arise much earlier, and the effect of gravity make itself apparent in the manner indicated. The investigation would seem to provide evidence of the necessity for very accurate balancing, and may afford complete explanation of those actual cases when annoying vibrations have been set up at a much earlier period than could have been anticipated by the designer. It is also suggested that the margin of safety allowed in practice on the usual critical speed value, as calculated, is about 30 per cent.

I also note Mr. Henderson's letter in the last issue of your journal. Since the accurate calculation, on the conditions laid down by Mr. Henderson, fails to give a clearer solution of the case of the De Laval rotor than had already been arrived at, I cannot accept his conclusion, that bearing I. supports the shaft at its inner edge, as altogether justified. It also seems to me that Mr. Henderson attaches an undue importance to the infinitesimal elastic strains that will be set up in the bearing and its housing.

I am very grateful to Mr. Henderson for his appreciative remarks on the article under discussion, and pleased that he has found it of interest.

Yours faithfully,
WM. KERR.

"Birkwood," Forrest-street, Airdrie, N.B.,
March 28, 1916.

TORSION STRESSES IN FRAMED STRUCTURES AND THIN-WALLED PRISMS.

TO THE EDITOR OF ENGINEERING.

SIR,—Mr. Ritchie, in his letter published in your issue of January 14, still appears to misunderstand the deduction and meaning of the theorem of §3 of my paper (ENGINEERING, October 15, 1915). That this theorem is not, as your correspondent states, at variance with the modern theory of torsion I hope to demonstrate in the present letter, and more fully in a paper now in course of preparation, in which I shall extend the method to the case of solid sections. I may state here that its application to sections considered by St. Venant and others gives results entirely in agreement with theirs, including the zero stress at the corner of a rectangular prism, to which your correspondent refers.

Mr. Ritchie confuses total shear across a section with shear intensity at a point within the section. He states that in my original paper "the shear stress at two points on the contour distant δs apart is assumed to be the same." It is the *total* shear which is assumed to be the same over any longitudinal section of the walls. The justification for this was given in my letter of December 17, 1915, as follows:—"In any hollow cylinder or prism subjected to torsion the stresses at both the inner and outer surfaces must be along the surface. If the walls are thin, there will not be any other component of appreciable magnitude introduced, and the forces acting on an element of the wall bounded by two cross-sections and two longitudinal sections will be along the edges of the element, as shown in Fig. 3 of my paper. . . . That the total longitudinal shear is constant over any cross-section of the walls parallel to the axis follows immediately from this. If the walls are thick, other conditions enter, and the above assumption will, of course, be incorrect."

It is this statement, and not the proof of the warping of the cross-section, as Mr. Ritchie appears to think, judging from the concluding paragraph of his letter, which constitues the justification of my method. Since the walls of the cylinder or prism are supposed to be thin, the shear stress, although usually slightly greater at the outer surface than at the inner surface, may be assumed to be uniformly distributed, and the shear stress intensity at any point of the contour may be taken as the total shear per unit of length, calculated from my theorem, divided by the thickness of the wall at the point considered. If the walls are of uniform thickness, the intensity of stress will be sensibly uniform throughout. In the case of a rectangular prism having thin walls of uniform thickness, this will be true except at the corners. At both the inner and outer corners the stress will, of course, become zero, as Mr. Ritchie states. This means that over a section of the walls from an outside corner to an inside corner the stress cannot be uniformly distributed. The total shear will, however, remain the same, and, since the thickness of the walls measured from outside corner to inside corner is $\sqrt{2}$ times the thickness at other points, this will probably not cause any undue stress intensity at any point of the section. All of this is quite in accordance with the hydrodynamic analogy quoted by Mr. Ritchie. An experiment on soap films by Prandtl's method would demonstrate exactly how the stress is distributed at the corners. The corners will affect the distribution of stress for a distance along the walls approximately equal to the thickness.

The theorem is not only true for a thin-walled section, but also may be applied to any portion of a solid or hollow section bounded by two neighbouring lines of shear. Using this, I have been able, as already stated, to solve various cases of solid shafts.

I must reiterate what I have said about hollow sections in my previous letter. Most of the existing formulæ assume, either explicitly as in St. Venant, or implicitly as in Antenrieth, that *the inner boundary is a line of shear for the solid shaft having the same outer boundary*. Even when the thickness of the walls is small, this does not give a section having *uniform* thickness of material. This is really the crux of the whole matter under discussion. A consideration of the hollow elliptical section will illustrate the point. The formula given by Mr. Ritchie in his first letter (November 5, 1915, page 467), viz.:—

$$f_{max.} = \frac{2\,T\,b}{\pi\,(a\,b^3 - a_0\,b_0^3)} = \frac{2\,T}{\pi\,a\,b^3\,(1-\gamma^4)} \qquad (1)$$

is true for a hollow cylinder having as outer boundary an ellipse of semi-major axis a and semi-minor axis b, and as inner boundary an ellipse having semi-axes a_0 and b_0 bearing the same ratio γ to a and b respectively, the inner boundary being a line of shear for the solid elliptical shaft. It is clear that, however large the ratio γ may be, the thickness of the walls of the cylinder will not be uniform, but that the thickness at the end of the major axis will be to the thickness at the end of the minor axis as a is to b.

Now if the theorem of § 3 of my paper be applied to this case,

$$S = \frac{T}{2\,\pi\,a\,b} \quad . \quad . \quad . \quad . \quad . \qquad (2)$$

where S is the *total* shear per unit length of the cylinder across the section of the walls. Assuming that, if the walls are thin, this shear is uniformly distributed throughout the thickness, the intensity of shear at the end of the minor axis is

$$f_{max.} = \frac{T}{2\,\pi\,a\,b^2\,(1-\gamma)} \quad . \quad . \quad . \qquad (3)$$

and at the end of the major axis is

$$f = \frac{T}{2\,\pi\,a^2\,b\,(1-\gamma)} \quad . \quad . \quad . \qquad (4)$$

Thus the ratio between f and $f_{max.}$ is the same as that found from the theory on which equation (1) is based.

If γ is large—*i.e.*, if the cylinder is thin-walled—the maximum stress calculated from (3) is practically the same as that calculated from (1).

For example, let $\gamma = 0.99$, then using equation (1):

$$f_{max.} = 50.76\,\frac{T}{\pi\,a\,b^2}$$

and using equation (3):—

$$f_{max.} = 50\,\frac{T}{\pi\,a\,b^2}$$

Thus the difference is approximately 1.5 per cent., which is close enough for all practical purposes. The accuracy of equation (2) is, of course, much greater than this. If $\gamma = 0.999$, the difference in the values of $f_{max.}$ found from the two formulæ practically vanishes. If, however, the cylinder has thin walls of uniform thickness t, the stress will be sensibly the same at all points of the contour, and its value will be given very approximately by:—

$$f = \frac{T}{2\,\pi\,a\,b\,t} \quad . \quad . \quad . \qquad (5)$$

Assuming the thickness of the walls to be $\frac{1}{100}\,b$, this would give:—

$$f_{max.} = 50\,\frac{T}{\pi\,a\,b^2}$$

Applying equation (1) to this case, and taking a section in which $a = 3\,b$:—

$$f_{max.} = \frac{2\,T}{\pi\,a\,b^2\left[1-\left(1-\frac{1}{300}\right)\left(1-\frac{1}{100}\right)^3\right]}$$

$$= 60.6\,\frac{T}{a\,b^2}$$

which is 21.2 per cent. too high.

It will be seen from the above that equation (1) is only applicable when the inner boundary is a similar ellipse to the outer—*i.e.*, when the inner boundary is a line of shear for the solid section.

The case of the rectangular prism is more complicated. The usual formula* given for the maximum stress is

$$f_{max.} = \frac{9}{2}\,\frac{T\,b}{b\,h^3 - b_0\,h_0^3} \quad . \quad . \quad . \qquad (6)$$

where h is the longer side and b the shorter side. A more correct value based on St. Venant's results† would be

$$f_{max.} = \left(3 + \frac{2.6}{0.45 + \frac{h}{b}}\right)\frac{T\,b}{b\,h^3 - b_0\,h_0^3} \quad . \qquad (7)$$

* Hütte, vol. i., page 589.

† Bach, "Elastizität und Festigkeit," sixth edition, page 317.

For a square prism having sides of length b, these equations become:—

$$f_{max.} = 4.5 \text{ and } 4.79\,\frac{T}{b^3\,(1-\gamma^4)}$$

respectively.

Antenrieth gives:—

$$f_{max.} = \frac{36}{7\,(1+\gamma^2) - 2\,\gamma^4}\cdot\frac{T}{A\,b}$$

where A is the actual area of the cross-section.

Let $\gamma = 0.99$. In this case,

$$f_{max.} = K\,\frac{T}{b^3},$$

where K = 121.5, according to equation (7), or 151.4, according to Antenrieth.

Thus the two formulæ give results differing about 24.6 per cent. This difference is large, and is due to the different assumptions made. A discussion of this point would be too lengthy to be entered upon here, but it is important to notice that both methods *assume* that the distribution of stress will follow the same law for the hollow as for the solid shaft—*i.e.*, that the inner boundary (a square) is a line of shear for the solid square prism. This is quite incorrect, even if the prism is thin-walled. The actual shape of a line of shear just within the boundary of a solid square shaft is a continuous closed curve which is practically parallel to the walls near the middle points of the sides, but deviates greatly near the corners.

The application of my formula to the case of the thin-walled square prism gives:—

$$S = \frac{T}{2\,b^2}.$$

This is true, whatever the shape of the inner surface, provided the walls remain thin. If the walls are of uniform thickness, the stress is sensibly constant over the contour except at the corners, where it becomes zero. Its value is given very approximately by:—

$$f = \frac{T}{b^3\,(1-\gamma)} = 100\,\frac{T}{b^3}.$$

This is lower than the value given by either formula (7) or formula (8), although it agrees more closely with the formula (7) than the latter does with (8). I believe it to be a very close approximation to the true value for the reasons stated above. The curve drawn in Mr. Ritchie's first letter from Antenrieth's investigation shows a stress varying very greatly over the section, and this could only be true for the thin-walled rectangle if the thickness of the walls varied considerably at different points.

Mr. Ritchie states that, according to my formula, a thin-walled section of any shape is as efficient as a thin-walled circular section having the same area of section. It is true that the total shear S across any longitudinal section of the walls will be the same if the area of the curve formed by the outer boundary is the same, and thus, if the thickness is uniform, the intensity of stress will be sensibly the same in all such cases. But the amount of material will vary as the perimeter of the section, and will thus be least for the circle. The angle of twist (December 17, page 623) also varies as the perimeter, and thus the circular section will also be the stiffest.

Mr. Ritchie entirely misunderstands my proof of the warping of the cross-section of a thin-walled prism. I do not, as he suggests, misunderstand what is meant by that term. My definition agrees with that given by Mr. Ritchie, and the analysis does not give "the closing in of adjacent plane sections," but the *alteration in shape of any one cross-section*, as is evident from the method of proof, and also from the form of equation (5) (December 17, page 623), which contains no term depending upon the distance between two sections. The warping is, of course, the same for all cross-sections, so that they remain parallel surfaces. Further, I do not assume, as your correspondent states, that an element of the contour of the cross-section undergoes a "change of length, which in itself infers a difference of stress at the two ends of the element." Under shear the rectangular element considered becomes a parallelogram. The changes ξ and η, in δs and δl respectively, are not changes in the lengths of the sides of the element, but changes in the position of one corner of the element, the opposite corner remaining fixed. This should be perfectly clear from the equation used—*i.e.*:—

$$\delta\,\theta = \frac{\xi}{\delta\,l} + \frac{\eta}{\delta\,s},$$

which is a well-known expression for such displacements under shear. It is, of course, necessary to assume one point of the cross-section to remain fixed in order to find the relative motion of other points on the contour.

I feel sure that a closer perusal of my original paper and letter of December 17, 1915, in the light of the above, will satisfy Mr. Ritchie of the validity of the methods used. The results which I hope to publish shortly as direct deductions from my theorem are in agreement with the results of the older methods of analysis, the truth of which Mr. Ritchie does not dispute.

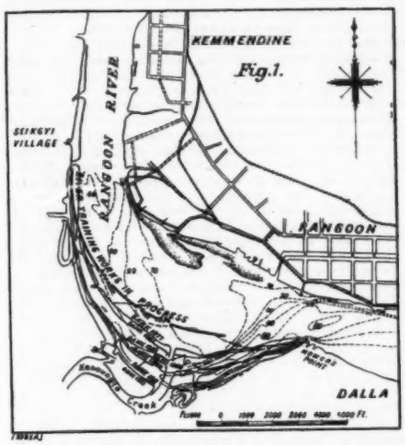
Yours sincerely,
CYRIL BATHO.

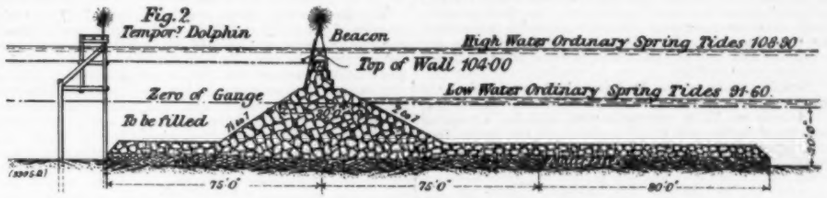
McGill University, Montreal, February 8, 1916.

RAILS IN THE UNITED STATES.—An average of upwards of 3,000,000 tons of rails are rolled annually in the United States, 75 per cent. being of 85-lb. section, or even heavier. Including fastenings, this involves an annual expenditure of 100,000,000 dols. for materials alone, in addition to the amount required for labour employed in laying such materials in tracks.

THE RANGOON RIVER-TRAINING WORKS.

SIR GEORGE CUNNINGHAM BUCHANAN, C.I.E., M. INST. C.E., ENGINEER.





CROSS-COMPOUND WINDING-ENGINES FOR THE CHISLET COLLIERY, NEAR CANTERBURY.

On Plate XXIX. we publish the first of a series of engravings which will illustrate in detail the principal features of two sets of powerful winding-engines recently constructed by Messrs. Fraser and Chalmers, Limited, Erith, for the Chislet Colliery, near Canterbury. It is intended to use these engines not merely for winding the coal after the colliery is in working order, but also during the operation of shaft-sinking. In its normal work the engine will have to lift 3¾ tons of coal from a depth of 1500 ft. in 40 seconds, or from a depth of 1800 ft. in a somewhat greater time. The total load carried and to be got under way at each wind is, of course, much greater, since each of the two three-deck cages weighs 11,800 lb., and the six tubs, 4030 lb. These two items are, of course, balanced, and only impose load on the engine by their inertia in starting and stopping. As no balance-rope is fitted, however, the net load on the engine is increased by the weight of 1500 ft. of 1¾-in. wire rope, which is equal to 7250 lb., making, with the coal, an aggregate unbalanced load of 15,650 lb. If required to operate at 1800 ft. depth, this figure will be increased by the additional length of rope needed. Though, as stated, the weight of the cages and tubs is balanced during the normal working of the engine, yet the latter is also required to be able to lift a full-loaded cage off the top dogs when the empty cage is landed at the bottom of the shaft. In this case the load to be raised is increased by that of one cage and a set of tubs, which is 15,830 lb., and against this has to be deducted merely the weight of the rope from the pit-head to the landed cage below. The maximum load which can thus come on the engine is 16,890 lb. When used for sinking operations the engine is required to be capable of lifting 600 gallons of water from a depth of 600 yards. The total load in this case will be 6000 lb. as the weight of the water, 2600 lb. as that of the bucket and chains, with 5380 lb. as the weight of the rope, making up a total of 13,980 lb. The brake-gear provided is capable of holding up these loads at any point of the shaft by the action of the brake-weights alone, whilst when these are assisted by the admission of steam to the brake cylinder the loads can be held even against the full power of the engine. The wear of the brake-blocks is taken up automatically, and provision is made by which the braking pressure is under the control of the enginemen.

THE RANGOON RIVER-TRAINING WORKS.*

By Sir GEORGE CUNNINGHAM BUCHANAN, C.I.E., M. Inst. C.E.

THE PORT OF RANGOON.

RANGOON, the capital of Burma, is situated in latitude 16 deg. 46 min. N., longitude 96 deg. 18 min. E., on the left bank of the Rangoon River, and 28 miles from the sea. It is to-day a modern city of 300,000 inhabitants, the capital of Burma, and the third port in the Indian Empire.

Until recent years very little was done to improve or develop the port. A Port Trust was created in 1879, but up to 1900 the Secretary to Government and Chief Engineer, Public Works Department, was the Chairman of the Port Commissioners *ex officio*, and the Collector of Customs, Rangoon, the Vice-President *ex officio*. With the increase of trade this arrangement became inadequate, and in April, 1901, the author was appointed Chief Executive Officer with the title of Chairman and Chief Engineer. Since that date 1,150,000*l.* has been spent on port works, exclusive of river conservancy, and modern deep-water wharves, lighted by electricity and equipped with hydraulic cranes and sheds and warehouses, have been provided.

The net registered tonnage of shipping entering the port in 1913 was 2,946,774, the ordinary port revenue 345,000*l.*, and the value of the trade 38,500,000*l.* The staple trade is rice, and of this commodity 1½ million tons, or 53⅓ million bushels, is exported annually. The work about to be described has cost close on 1,000,000*l.*, and it is non-revenue producing, but the issue at stake was the preservation of the third port in the Indian Empire from threatened destruction.

THE RANGOON RIVER.

The Rangoon River is formed by the junction, about 5 miles above the town of the Panhlaing and Hline Rivers; the former is an effluent from the Irrawaddy, the latter is a true river rising in the Pegu Yomas. Three miles below the town the Rangoon River is joined by the Pazundaung River and the Pegu River, and it finally flows into the Gulf of Martaban 28 miles below Rangoon. The maximum combined discharge of fresh water and tidal water is approximately 1,000,000 cusecs, and the average speed of spring tide currents 6.06 ft. per second on the flood, and 6.65 ft. per second on the ebb.

TRAINING-WORKS.

Although there is no bar at the mouth of the river, engineering problems of considerable magnitude are presented by the conditions immediately above and below the wharves and anchorages.

In the one case a large sandbank at the junction of the Pegu River, Rangoon River, and Pazundaung Creek, 3 miles below the wharves, has for many years been an impediment to trade and navigation, whilst in the other case serious erosion of the right bank of the river above Rangoon has threatened to divert the main stream from Rangoon to the south side of the river.

The results of this continued erosion of the right bank have been threefold:—

1. The deep-water channel above Rangoon has been diverted year by year farther away from the Rangoon foreshore, and large sandbanks have formed on the Rangoon side of the river immediately above the town.

2. The ebb tide swinging round the eroded bend in a deep contracted channel has emerged from it at the projection known as Mower's Point with great force, and obliquely across the river to the Rangoon bank, causing erosion of the river bed and undermining of the Port Commissioners' wharves and jetties.

3. The anchorage accommodation, in a port peculiarly dependent upon it, has been seriously curtailed by the difficulty of laying many fixed moorings in a tideway subject to strong cross currents.

In September, 1903, the author issued a preliminary report, stating that, in his opinion, in the event of no protective measures being taken, the deep-water channel in front of the wharves would be diverted from the left bank to the right bank of the river, the existing Port of Rangoon would silt up, and the problem would be changed from training the river to making a new harbour elsewhere. He proposed, by the construction of a training-wall 14,000 ft. long, to restore the right bank approximately to its old line of frontage, the wall to be constructed with a foundation course of mattresses made of bamboo and brushwood surmounted by a superstructure of open crib-work.

Recognising that the project was one of considerable novelty and open to various points of view, the author suggested to the Port Commissioners that some expert of proved experience should be associated with him in the matter who would write an independent report, and the Port Commissioners invited the late Mr. P. W. Meik, M. Inst. C.E., to visit Rangoon and favour them with his opinion.

Mr. Meik accepted the invitation, and after studying the subject, said that in his opinion the author was correct in his diagnosis, and unless steps were promptly taken to bring the river-channel back to the position it probably occupied fifty years ago, it would in a very few years be necessary to transfer the quays and wharves of the port to another locality. He pointed out that the problem was undoubtedly important and difficult, and he was not aware of any river-training works having been carried out in any part of the world under similar conditions.

The whole of the year 1904 and a great deal of 1905 were spent in making surveys, and in December, 1906, a scheme prepared jointly by the author and Mr. Meik was presented to the Port Commissioners, the works proposed comprising:—

1. The construction of a training-wall built of a series of bamboo and brushwood mattresses, loaded with stone.

2. The dredging of a new channel.

3. The removal of the projection of land known as Mower's Point.

The plans were approved by the Port Commissioners and the Government of Burma, and were in due course forwarded to the Government of India, where they were subjected to severe criticism by the Inspector-General of Irrigation, Mr. (now Sir) John Benton, who, whilst agreeing that immediate and effective action should be taken, thought the design too complicated for practical execution under the great difficulties of the situation.

A committee of engineers was appointed by the Government of Burma, who, after consideration of alternatives, decided in favour of a training-wall, but definitely rejected mattress construction as impracticable. They proposed a pier or gantry consisting of pairs of steel piles set 20 ft. apart and strongly braced, around which would be constructed a rubble wall up to low-water level, after which permeable bamboo screens were to be fixed to the piles in order to cause partial obstruction to the flow of water over the wall. They also proposed to leave Mower's Point untouched, and to dredge a channel in front of the training-wall.

The author submitted a rider to the report, in which he argued against the construction of the steel gantry, estimated to cost 140,000*l.* He proposed to open granite quarries on an island 135 miles away, and to convey stone to the work in 1000-ton steam hopper-barges, and he contended that the gantry would interfere with the discharging of the stone from the barges.

Sir John Benton deprecated the omission of the gantry, on the ground that it was the only way of obtaining complete and effective control of the flow of the water throughout the tidal range of 22 ft. After further consultation with Mr. Meik, and also with Dr. Corthell, the author submitted, in 1907, a new scheme for a half-tide wall to be built of granite-rubble deposited on a foundation course of flexible bamboo and brushwood mattresses; but Sir John Benton reported to the Government of India that the proposals appeared to be insufficient for controlling the maximum tidal flow, and advised omission of the mattresses, which he considered a grave source of danger.

A tour made by the author in the United States, Canada, and China at this stage confirmed him in the opinion that foundation mattresses were a *sine qua non*, but that a flexible brushwood which could be obtained locally was preferable to bamboos, and in December, 1909, he submitted another amended project. The proposals were approved by the Port Commissioners and the Government of Burma, but the Government of India expressed dissatisfaction with the proposals, and said they were unable to sanction the large sum provided for mattresses. Matters had come to an *impasse*, but at this juncture a new Governor, Sir Harvey Adamson, came to Burma, who examined the project, represented his views to the Government of India, and urged that there could be no progress until the controversy was brought to a conclusion. Finally, in October, 1910, the Government of India sanctioned the plans with an estimate for 900,000*l.*, which was subsequently increased to 1,000,000*l.* Although the scheme as a whole did not receive the sanction of the Government of India until October, 1910, sanction had been previously accorded to the purchase of the dredger and to the opening-out of quarries.

MATERIALS, PLANT AND TEMPORARY WORKS.

Stone.—The estimated quantity of stone required was 28,000,000 cub. ft., and the actual quantity used was 27,943,000 cub. ft., which cost in the work 1*l.* 15*s.* 8*d.* per 100 cub. ft. 18,000,000 cub. ft. was dumped from steam hopper-barges and 10,000,000 cub. ft. placed by hand. The latter was obtained from quarries on the line of the Pegu-Moulmein Railway, 156 miles from Rangoon, and conveyed by rail to a riverside station. The dumped stone was obtained from quarries opened up on an uninhabited island named Kalagouk, situated off the Tenasserim coast. The establishment of men and plant on the island capable of quarrying 1000 tons of rubble per diem, and its transfer to Rangoon in 1000-ton steam hopper-barges, proved an arduous task, and many

* Abstract of paper read before the Institution of Civil Engineers, Tuesday, March 21, 1916. In addition to the abstract we publish a number of illustrations which will add to the interest of the paper. Fig. 1, above, is a map of the harbour at Rangoon, Fig. 2 a section of the training-wall, Figs. 3 and 4, Plate XXVIII., are views of a mattress just completed and one being sunk, Figs. 5 and 6 show the wall in course of construction, Fig. 7, Plate XXX., the completed wall, Fig. 8 the pipe-line from the dredger, while Fig. 9 is a general view.

difficulties arose, not the least of which was the climate, the rainfall being between 200 in. and 260 in. per annum, and occurring chiefly during five months of the year. Owing to the shallowness of the water near the shore a pier was built at the requisite distance out, and two Lidgerwood cableways were installed, a radial travelling cable being used for handling the stone on the land and a fixed cable for conveying it to the pier alongside which lay the steam hoppers. The cost of opening out and equipping the quarry, including purchase of three steam hoppers, was 165,799*l.*

Dredging-Plant.—The dredging-plant consisted of the twin-screw suction-pump dredger Pelican, which was fitted with two 30-in. pumps having together a nominal capacity of 80,000 cub. ft. of sand and silt per hour, lifted from a depth of 55 ft., and delivered through a pipe-line 3000 ft. long.

CONSTRUCTION OF THE TRAINING-WALL.

The wall above low-water level is 10,000 ft. long, extending from Seikgyi to the neighbourhood of Mower's Point, and there is an extension 2700 ft. long to Mower's Point, which finishes at 30 ft. below low water, so as to leave a passage for the Kanaungto creek. Thus the main deep-water channel of the river is crossed in two places, the wall is tangential to high-water mark at Seikgyi and sweeps southward and eastward in a curve of 6000 ft. radius for a distance of 8500 ft., after which it takes a straight course approximately parallel to the left bank of the river. The direction of the straight portion is so aligned as to cut through Mower's Point in line with the right bank of the river opposite Rangoon, so that if and when the point is ultimately removed there will be a straight channel of uniform width opposite the town.

The top of the rubble wall is 95 ft. above the datum of the Port of Rangoon and 1 ft. above low water of ordinary neap tides in the dry season. A superstructure of stone enclosed in reinforced-concrete slabs has been built on the rubble mound to a height of 104 ft. above datum, or 5 ft. below high water of ordinary spring tides. Between the present right bank and the wall is an area at high water of about 300 acres, which it is intended to fill as far as possible by the natural deposition of silt, but the complete reclamation of the bight is not within the scope of the present scheme. The following was the general programme of operations:—

1. Timber dolphins were erected 500 ft. apart for the entire length of the work.

2. A carpet of mattresses was laid at a uniform width of 230 ft., extending from Seikgyi to the end of the proposed wall, and covered with sufficient hand-placed stone to sink and retain them in position.

3. Hopper-barges tipped granite over the mattresses to a thickness of 3 ft. 9 in., and thereafter on the centre-line of the wall.

4. The wall from level 85—*i.e.*, 5 ft. below zero, or low water of ordinary spring tides, dry season, to level 95—*i.e.*, 5 ft. above zero, or low water of ordinary spring tide—was built by hand-placed rubble.

5. The wall from level 95 to level 104—*i.e.*, 14 ft. above zero, or low water of ordinary spring tide—was built of reinforced-concrete slabs for face work, filled in with granite-rubble.

6. Simultaneously with the construction of the wall the pipe-line dredger was employed in making a series of cuts along the line of the new channel outside the wall and pumping the material behind the wall.

MATTRESSES.

Each mattress was 125 ft. long by 80 ft. wide by about 3 ft. thick, and there were in all 224 mattresses, requiring about 22,000 bundles of brushwood per mattress. The mattresses were towed into position by a steam-tug, loaded with stone, and sunk. The average weight of stone required to sink a mattress was about 80 tons, but 320 tons was always deposited at the time of sinking, and the average time to sink a mattress and cover with 320 tons of stone was 20 minutes, 120 to 150 men, all told, being employed.

CONSTRUCTION OF THE WALLS.

Up to Level 85.—The total quantity of stone dumped was 18,000,000 cub. ft., and the three hopper-barges were kept steadily at work depositing stone wherever dumping was most convenient, one great benefit derived from the carpet of mattresses being that there was no scar end, and stone could be dumped anywhere without pot-holes being formed by the numerous eddies set up.

From Level 85 *to Level* 95.—This was done almost entirely with railway stone brought to the site in 80-ton barges and hand-placed on the wall. A good day's work was twelve barges, depending on the tides, and it generally took 20 minutes to discharge a barge, thirty coolies per barge being employed.

From Level 95 *to Level* 104.—At the author's instance the question of the procedure after level 95 was reached had been left for consideration as the necessity arose. When the wall had crossed the main channel of the river and was approaching low-water level in height, it became apparent that the level 95 was too low, but for reasons which had not occurred to any one. The safety of the wall was not affected, as not a single stone was shifted either on the crest or the side slopes during the strongest tide, but the head of water on the ebb-tide on the outside of the wall caused by the difference of level of the water inside and outside the embayment was such as to scour deep holes inside the embayment and dispel all idea of natural accretion. It was finally decided to build a superstructure of reinforced-concrete slabs, 3 ft. by 3 ft. by 4 in. thick, placed on the wall in three tiers, the bottom tier being 9½ ft. apart, tied together with 1-in diameter steel tie-rods protected from corrosion, and filled in with granite rubble. 17,767 slabs were made on the spot by coolie labour, and the whole superstructure, 9290 ft. long by 9 ft. high, was completed in nine months at a cost of 13,655*l.*, or about 30s. per lineal foot. The work has proved completely successful.

DREDGING.

The dredger was set to work on July 1, 1912, to make a series of parallel cuts 250 ft. wide, joining up the 20-ft. contour in front of the wall, the spoil being deposited behind the wall. The dredger's best work was done after the wall had crossed the deep-water channel, in making continuous cuts in front of the wall up to a depth of 30 ft. below low water, thus gradually assisting the passage of the river down the new channel. Dredging was stopped at the end of August, 1913, by which time 54,000,000 cub. ft. had been removed and a channel 800 ft. wide by 30 ft. deep below low water had been formed.

FINANCIAL.

The sanctioned estimate for the work was 1,000,000*l.* for a half-tide wall, and the actual cost was 921,783*l.* for a high-water wall. Funds were obtained by a grant of 50 lacs of rupees (333,000*l.*) from the Government of India, and the issue of four per cent. debenture loans by the Port Commissioners.

RESULTS.

The effect of the work may be summarised thus:—

1. The deep-water channel has been brought back to the position it formerly occupied, and there is now a navigable channel with a depth of 50 ft. below low water in front of the wall.

2. The sand-banks on the left bank of the river which threatened Rangoon have very considerably diminished.

3. Since the commencement of the work 19,195,100 cubic yards of silt, exclusive of dredged spoil, has been deposited inside the embayment, the whole of which is now above low-water level, the rate of deposition having averaged 16 in. monthly over the whole area, and been as much as 3 ft. monthly in the deep water.

4. The cross currents from Mower's Point have disappeared, and the ebb and flood-tides run nearly parallel with each other, rendering dredging alongside the wharves unnecessary except at long intervals. It is now tolerably certain that the wharves would have been endangered by excessive scour had the wall followed the alignment proposed by Sir John Benton's Committee.

SEARCH FOR NEW COAL-FIELDS IN ENGLAND: ERRATUM.—In our Note on page 285 of last week's issue the location of the Kent coal-field was inadvertently stated to be west and north-west of Dover, instead of east and north-east.

GERMAN TRADE WITH FOREIGN COUNTRIES.—The Paris journal *L'Industrie Electrique* gives publicity to the following article taken from the German journal *Helios*:—"The question has been asked as to whether it would be more advantageous for our market to request payment for our goods sold to foreign countries in marks or in the currency of the said countries. The observance of most precise rules in this respect is of the greatest importance for the regulating of our exchange. In the present circumstances, German sellers must certainly be advised to receive payment in the currency of foreign countries, and not in marks. Since the greater part of the money due for German sales is concentrated in the Reichsbank, and since the latter has payments to make in those same countries, it will by this means be enabled to prevent an inordinate rise in the rate of exchange. The task will be considerably facilitated if, in future, all contracts signed with foreign countries stipulate for payment in the currency of the said countries. On the other hand, in the case of sales to Austria and to countries of the Balkan Peninsula, payments should, as a matter of course, be requested in marks." The article, says the French journal, is entitled "Payment in Foreign Currency to be Demanded for Sales (of German goods) to Holland, Scandinavia, and Switzerland;" a proper title would have been: *Res angusta domi*.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.—At the third annual general meeting of the Institution of Petroleum Technologists, held at the London Chamber of Commerce, on the 22nd inst., Sir Boverton Redwood, Bart., D.Sc., F.R.S.E., retiring from the presidency in conformity with the by-laws (after two years' tenure of that office), referred to the meritorious public services of his successor, Professor John Cadman, C.M.G., D.Sc., M. Inst. C.E., and congratulated him upon the honour recently conferred upon him in being made a Companion of the Order of St. Michael and St. George. In taking the chair, Professor Cadman paid an eloquent tribute to the abilities of his predecessor, employed unreservedly in the interest of his country as technical adviser of several departments of the Government, and remarked that the foundation and subsequent success of the Institution were largely due to Sir Boverton's energetic action. The Vice-Presidents and Council for the ensuing year are:—Vice-Presidents: The Right Hon. Lord Cowdray of Midhurst, Sir Thomas H. Holland, K.C.I.E., D.Sc., F.R.S., and Sir Boverton Redwood, Bart., D.Sc., F.R.S.E. Council: Alfred G. Adams, Herbert Allen, Sir Robert Balfour, Bart., M.P., Captain R. W. Barnett, M.A., Herbert Barringer, M. Inst. C.E., M.I. Mech. E., M.I.N.A., George T. Beilby, LL.D., F.R.S., Edwin R. Blundstone, B.A., F.C.S., Andrew Campbell, John T. Cargill, Major A. Cooper-Key, C.B., E. H. Cunningham Craig, B.A., F.G.S., Arthur W. Eastlake, M. Inst. M.E., A.M.I. Mech. E., C. Greenway, T. C. Palmer, Assoc. M. Inst. C.E., F. Mollwo Perkin, Ph.D., F.I.C., F.C.S., and Robert Redwood, F.C.S.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

South Yorkshire Coal Trade.—The coal trade in South Yorkshire has not yet fully recovered from the disorganisation caused by the snowstorm of a fortnight ago, and the present spell of severe weather is likely to retard any efforts to improve the general situation. Orders of all descriptions have accumulated, and collieries are unable to meet the pressing demands made upon them. The railway workings have also suffered from the same cause, but are now much improved. Delays in the rail-borne traffic and the scarcity of wagons revived the question of the pooling of wagons. No definite steps are being taken, as the matter is still being considered by the Board of Trade. Second-hand wagons are selling at 83*l.*, but the price of new ones—125*l.*—is regarded as being prohibitive, especially as delivery is uncertain. The demands for manufacturing fuel are beyond the capacity of the collieries to supply. The house-coal position is to be compared with what is usually experienced at the beginning of winter rather than in spring. For steam and hard qualities munition works, gas and electricity establishments are the largest customers, but chiefly on account of contracts; the position of other industrial undertakings is unenviable. There is little free coal on the market, and even shipments are on a much smaller scale than usual. Small coal and coke are in full request. Blast-furnace coke and steel-melting coke are greatly desired by the large works. Quotations:—Best branch hand-picked, 20s. 6d. to 21s. 6d.; Barnsley best Silkstones, 17s. 6d. to 18s. 6d.; Derbyshire best brights, 17s. 6d. to 18s. 6d.; Derbyshire house, 16s. to 17s.; best large nuts, 15s. 6d. to 16s. 6d.; small nuts, 15s. to 16s.; Yorkshire hards, 16s. 6d. to 17s. 6d.; Derbyshire hards, 16s. to 17s.; best slacks, 12s. to 13s.; seconds, 10s. 6d. to 11s. 6d.; smalls, 8s. to 9s.

Iron and Steel.—The position in the market is steadier than for some time past and prices are not fluctuating so readily. The demands remain unusually heavy and the business transacted is at the top figures allowed by the Government scale of rates. Hematites are easier, the recent strong line taken by the Government having had a salutary effect. West Coast remains about 136s. with delivery here, whilst East Coast is marked at 126s. 3d., a drop of fully a sovereign on last month. This, of course, is due to the enforced Government maximum. Foundry-iron makers are still pressed for full supplies. Lincolnshire brands are 91s. 3d. and Derbyshire 89s. 6d., delivered in Sheffield, whilst the respective forge grades are 90s. 3d. and 87s. 6d. Whereas both Lincolnshire irons are about the same prices as in February, Derbyshire qualities are 2s. to 2s. 6d. dearer. Bar iron is quoted at 13*l.* 10s., and sheets at 20*l.* The city's engineering resources, which are continually being enlarged, are fully occupied on all classes of work. Official figures to hand show that in the month of February there were more workmen employed in the Sheffield steel industry that at any other period since the commencement of the war. The position with regard to steel billets grows easier. It is stated that the Swedish manufacturers' demands for Yorkshire coal to enable them to produce steel billets have been met to a certain extent. The output of billets has accordingly increased, and Sheffield has already reaped some benefit from the changed policy. Prices are still abnormally high. There is not much activity in the finished iron trade, and, except in foundries which are engaged on the manufacture of cast-iron bombs, there is little regular work. Electro-plate and silver firms are now partially on munitions, as they have adapted part of their works for the shell-finishing processes. In addition, the needs of the Army in the way of spoons and forks are being supplied. Further Government tenders this week include 15,000 electro-plated tablespoons, 13,600 lever-knives, 5740 corkscrews, and 11,000 machets. On behalf of the French Government orders are being placed for enormous quantities of knives and forks; whilst the Russian authorities have large demands for files. A twelve months' contract for the supply of "Crutch" tool-steel has been placed with Messrs. A. Blyde and Co., Wallace Steel Works, Sheffield, by the Middlesbrough Corporation. Southampton Corporation have given a large order for tramway-points and crossings to a well-known firm in this city. Large requests continue to arrive for garden and farm tools, and all demands cannot be met. Prices are higher than a year ago. The Colonial and foreign business shows no signs of falling off, and the latest mails include indents for steel, saws, wire, files, machets, and electro-plate.

CONTRACTS.—The Monometer Manufacturing Company, Limited, inform us that the Monometer patented furnaces, melting furnaces, hardening furnaces, and heat-controllers are in great demand for war work, for the melting of lead, Admiralty metal, aluminium, tin, zinc, &c. They give us a list of thirty-two British and foreign firms who have recently acquired one type or another of their furnaces and heat-controllers.

OPENINGS FOR BRITISH TRADE.—Since the outbreak of the war, applications have been received in the Commercial Intelligence Branch of the Board of Trade from a large number of firms in all parts of the United Kingdom and abroad who wish to get into communication with United Kingdom manufacturers or producers of various classes of goods which have previously been obtained from Germany and Austria-Hungary. The Commercial Intelligence Branch publishes regularly in the *Board of Trade Journal* detailed lists of the articles wanted.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Glasgow Pig-Iron Market.—The pig-iron market continued dull and lifeless last Wednesday afternoon, the only change noted being an advance of 6d. per ton, to 89s., on sellers' closing quotations. On Thursday morning another advance of 1s. per ton took place and in the afternoon this was further added to, 91s. per ton being reached. While no business was done on Friday, sellers' quotations at the close dropped to 90s. at the morning session, no change taking place in the afternoon. Monday's market was again idle, but the tone was firm and prices rose, sellers being quoted 92s. per ton at the close of the forenoon session. The afternoon showed no change and prices still remained nominal. Complete idleness prevailed on Tuesday, prices continuing on the same level, and the same conditions mark the market this (Wednesday) forenoon.

Scotch Steel Trade.—While war work continues to monopolise the bulk of the output, some of the local producers are making an effort to put through a few mercantile orders after the Government contracts on hand are completed. But little of this can be managed, however, for the demands of Government are insistent and incessant, the sectional mills being almost exclusively employed upon the production of shell-bars. Plates, too, are in great request for the export trade, although in small demand for the home market. Indeed, considering the difficulties which seem to have arisen in connection with the adjustment of maximum prices for all classes of finished steel, customers are holding back orders for ordinary mercantile business which would otherwise have been placed with local producers. Labour is also proving a most serious problem, more particularly during the past few weeks, and although many thousands of women are now employed in the various munition factories and turning out highly finished workers, they are not entirely able to replace the men who have joined the colours. Notwithstanding these difficulties, however, the utmost activity prevails at all the producing works in the West of Scotland. Prices keep very firm, although no appreciable advance has taken place within the past week. Boiler-plates run up to about 14*l.* 15s. per ton; shipplates are 13*l.* 10s. or thereabouts; and angles, greatly in demand, are 13*l.* 10s. and up—all less 2½ per cent.

Malleable-Iron Trade.—Large quantities of malleable iron continue to be turned out; indeed, there is not the slightest appearance of any slackening off. Of course practically the whole output is required on war account, if not directly, at least indirectly, and makers are faced with the same difficulties as are the steelmakers—shortage of labour. While manufacturers are getting chary of quoting, prices remain firm, and "Crown" bars may be 13*l.* 10s. per ton or 14*l.*—less, of course, the customary 5 per cent. discount—according to specification.

Scotch Pig-Iron Trade.—Little change falls to be reported in the conditions affecting the local pig-iron industry. Makers remain in a strong position, and the demand is unabated, hematite especially being in constant request, although the limitation of price has not yet been definitely settled. Various difficulties have been encountered, notably those pertaining to the cost of inward ore and the high freight charges, which are decidedly retarding a satisfactory arrangement being arrived at. The effect of the fixing of home prices has been of so much value in the way of steadying the market that it is hoped the other will soon follow. The scarcity of No. 1 foundry iron is being severely felt, but from the following it will be seen that prices are much on the level of last week:—Summerlee and Langloan, 125s. per ton; Clyde, Calder, and Gartsherrie, 127s. 6d. (all shipped at Glasgow); Eglinton, 120s.; Glengarnock, 125s. (both at Ardrossan); Dalmellington, 122s. (at Ayr); and Shotts, 127s. 6d. (at Leith).

Clyde Valley Electrical Power Company.—On Wednesday last, Mr. F. C. Gardiner, in presiding at the usual half-yearly meeting of this company, made interesting reference to the highly satisfactory increase of profit which has just been made public. This, he asserts, is entirely due to the additional demands for power made necessary by the extraordinary amount of war work undertaken in the area supplied by the company.

MARINE SURVEYORS AND NAVAL ARCHITECTS AND MILITARY SERVICE.—Marine surveyors and naval architects who are not definitely identified with the firms actively engaged in the construction of warships, but whose services are still of the greatest importance indirectly in connection with the war, have experienced difficulty in applying for exemption from military service. The Board of Trade Committee concerned with the definition of reserved occupations have also experienced this difficulty, recognising that many marine surveyors and naval architects ought to be exempted. The Board of Trade Committee therefore approached the Councils of the Institution of Naval Architects and the Institute of Marine Engineers with the request that these organisations should appoint a committee to co-operate with the Board of Trade Committee in dealing with applications for exemption. This committee has been formed, and Mr. Arthur Dansie, assistant secretary of the Institution of Naval Architects, is acting secretary to the committee. Marine surveyors and naval architects who desire to be exempted from military service, owing to the work they are doing for the furtherance of the war, should make application to him, giving their name, address, and age, and stating whether married or single, and the ground on which they base their claim for exemption.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—The serious scarcity of pig-iron is causing much anxiety, and, in fact, something approaching a famine in the commodity is feared. Demand from abroad continues heavy, and there is a growing feeling that, in order to satisfy home requirements, exports will have to be further curtailed. So far this year exports of pig-iron from the Tees to neutral countries approach 40,000 tons. The local committee appointed by the Ministry of Munitions to regulate deliveries of pig-iron for due protection of needs of home consumers have taken offices here, and will be carrying out their duties next week. Whether or not they will interfere with shipments is not known, but it is a very probable contingency. The export quotation of No. 3 Cleveland pig-iron is now 91s. f.o.b., but some business has been put through this week at 91s. 6d. No. 1 is very scarce, and for export is 96s. 6d. For home consumption, No. 3, No. 4 foundry, and No. 4 forge all stand at the fixed maximum of 82s. 6d., but some home users are reported to be prepared to pay merchants a commission on that figure for prompt delivery.

Hematite Iron.—There is next to no business passing in East Coast hematite pig, due to the facts that iron is not purchasable for supply until after June, and most makers have sold as far ahead as they care to commit themselves. For home consumption Nos. 1, 2, and 3 still stand at the fixed maximum of 122s. 6d.; and the export price remains at 140s.

Stock and Shipments of Pig-Iron.—Practically the only stock of pig-iron in existence is that in the public warrant stores, and to meet current needs it is being steadily drawn upon at a rate which threatens its absolute disappearance at no distant date. The withdrawals this month average little short of 1000 tons per working day. The stock in the warrant stores now stands at 59,123 tons, 56,745 tons of which is No. 3 Cleveland, and 2378 tons other qualities of Cleveland iron deliverable as standard. Since the beginning of the month 23,661 tons of No. 3 and 407 tons of standard iron, making a total of 24,068 tons, have been taken from the stores. Shipments of pig-iron from the port of Middlesbrough during March are round about 50,000 tons, which is equal to those of the previous month, and four times the quantity that was shipped during March last year.

Coke.—Demand for coke for local use keeps good, and business is understood to be still passing for home consumption at the fixed maximums of 28s. at the ovens for average blast-furnace kinds, and up to 30s. 6d. at the ovens for qualities low in phosphorus.

Foreign Ore.—There is very little doing in foreign ore. Consumers show little inclination to buy, notwithstanding the offer of the Government as regards freights. In the ordinary way market rates are still based on 43s. ex-ship Tees for Rubio of 50 per cent. quality. That, however, is assuming the freight Bilbao-Middlesbrough to be 26s. 6d.; but with the Government arrangement of a freight basis of 17s. the price of best Rubio is brought down to the intended fixed maximum of 34s. With two days' unloadings not included, the imports of foreign ore to the port of Middlesbrough during the third month of the year amount to 117,127 tons.

Manufactured Iron and Steel.—Manufacturers of finished iron and steel continue to produce Government work at great pressure, so much so that they have little time to heed the numerous ordinary commercial inquiries that are in the market. Prices all round are very strong. The following are among the principal market quotations:—Common iron bars, 13*l.* 10s.; best bars, 13*l.* 17s. 6d.; double best bars, 14*l.* 5s.; treble best bars, 14*l.* 12s. 6d.; packing iron (parallel), 10*l.*; packing iron (tapered), 11*l.* 15s.; iron ship-plates, 11*l.* 10s.; iron ship-angles, 13*l.* 10s.; iron ship-rivets (¾-in. diameter), 16*l.*; iron ship-rivets (½-in. diameter), 17*l.*; steel bars, 13*l.* 10s. to 14*l.*; steel ship-plates, 11*l.* 10s.; steel ship-angles, 11*l.* 2s. 6d.; steel joists, 11*l.* 2s. 6d.; steel strip, 13*l.* 10s.; steel hoops, 14*l.*; and heavy sections of steel rails, 10*l.* 17s. 6d.—all less the customary 2½ per cent. discount, except rails, which are net f.o.b.; and steel joists and steel shipbuilding material, which are net at works.

BRITISH GAS INDUSTRIES.—The Society of British Gas Industries met on Wednesday evening in the Trocadero Restaurant for their eleventh annual meeting, when the new Chairman of the Council, Mr. H. M. Thornton, J.P., delivered an address on "The Industrial Outlook and Its Relation to the Gas Industry." The speaker sounded a note of optimism at the very outset when he spoke in detail of the varied factors which go to make up "the almost incredible strength of our Empire;" but he warned his hearers that the supremacy which awaits us in the future can only be won by continued and combined national effort. State aid for industry by means of an extension of the Commercial Branch of the Board of Trade—that is to say, industrial administration by business men on business lines; improved relations between capital and labour; a revision of our educational system in the light of new requirements, and the establishment of schemes for industrial research as it is known in America, were among the many aspects of the industrial situation upon which the speaker had some useful suggestions to offer. He reviewed the important part played by gas in the war, and said that gas undertakings were united in doing their utmost to promote the engineering and other conditions essential to the supply of cheap gas in the various processes of munition works.

NOTES FROM THE SOUTH-WEST.

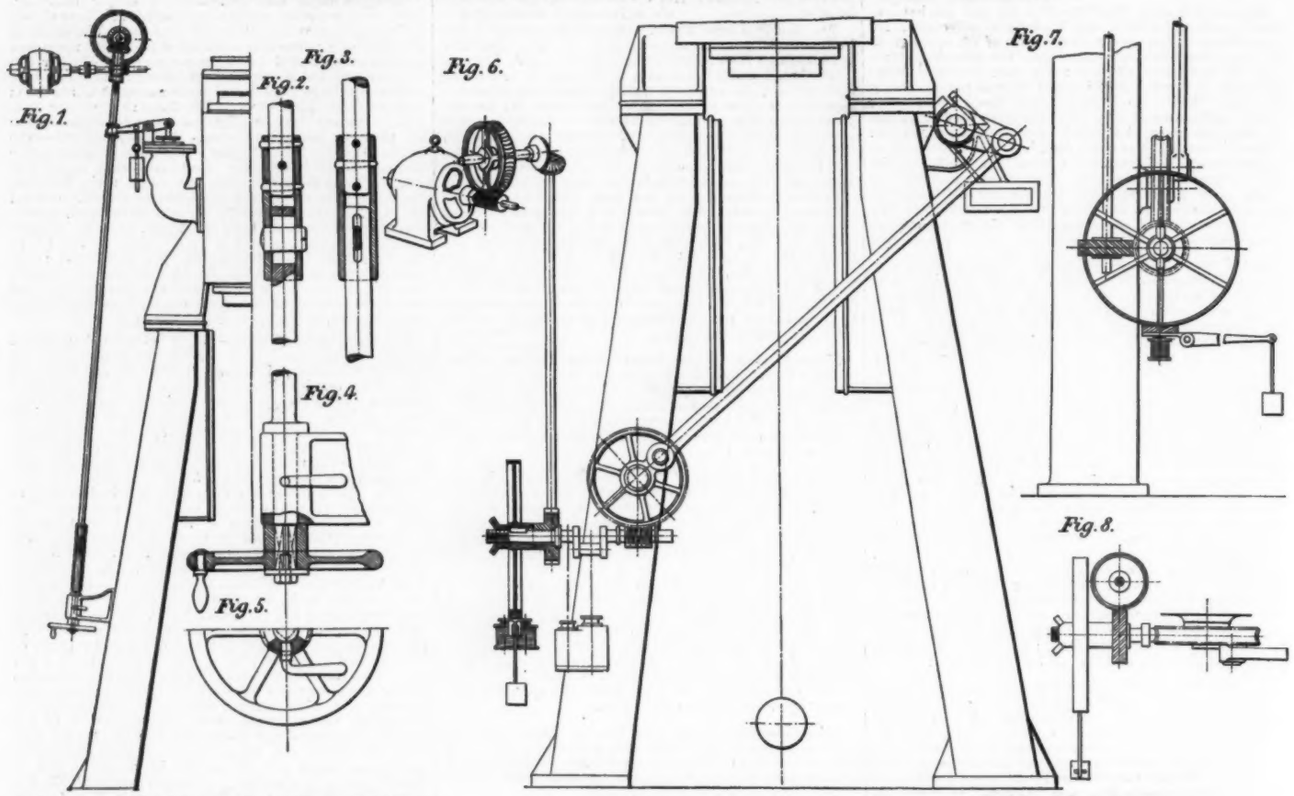
Cardiff.—Steam coal has shown a strong tendency. Most colliery owners are heavily booked, and have shown little eagerness to entertain new business. Under these circumstances quotations have ruled high, and the prices asked have exceeded anything yet realised, 40s. per ton being named for non-Admiralty descriptions. The best Admiralty large has been, to some extent, nominal; secondary qualities have made 34s. to 35s. per ton, while ordinary dry descriptions have brought 32s. to 33s. per ton; best bunker smalls, 18s. to 19s.; and cargo smalls, 12s. to 15s. per ton. Current quotations for bituminous coal have been:—Best households, at pit, 23s. to 24s.; No. 3 Rhondda large, 33s. to 35s.; No. 3 smalls, 21s. 6d. to 22s. 6d.; No. 2 Rhondda large, 28s. to 30s.; and No. 2 smalls, 16s. to 17s. per ton. The latest quotation for patent fuel has been 36s. to 38s. per ton. Special foundry coke for export has been quoted at 57s. 6d. to 62s. 6d.; good foundry coke, 52s. 6d. to 57s. 6d.; and furnace coke at 42s. 6d. to 47s. 6d. per ton. As regards iron ore, Rubio has made 39s. to 40s. per ton, upon a basis of 50 per cent. of iron, and charges, including freight, insurance, &c, to Cardiff or Newport.

Western Trade Matters.—Mr. F. Glasbrook presided at the annual meeting of the Penrikylen Navigation Colliery Company, Limited, at Cardiff, and observed that, in his opinion, the company was in a sound financial position. After the cost of new works, debenture interest, &c., had been provided for, there remained a balance of 58,837*l.* The machinery and plant had been maintained in good order, but a new air-compressor had not yet been delivered.—The number of steamships which cleared from Penarth Dock last year was 2159, as compared with 2173 in 1914. The number of sailing ships which cleared from the port last year was 448, as compared with 548. The total exports from Penarth in 1915 were 3,153,461 tons, as against 3,993,583 tons in 1914. In these totals coal and coke figured for 3,145,957 tons and 3 992,465 tons respectively.—At the annual meeting of the Rhymney and Aber Valleys Gas and Water Company at Caerphilly, the chairman (Mr. E. M. Hurran) stated that during the past year the company had expended 13,752*l.* on capital account, mainly on new gas works and new water mains. The revenue account, the chairman added, showed a profit of 18,518*l.*, and it was decided to pay a dividend of 5 per cent. upon the ordinary shares for the past twelve months. Owing to the war new gas works at Caerphilly could not be completed. New freight records have been established at Cardiff. Genoa options have been carried to 5*l.* per ton, two steamers—one of 3200 tons and another of 4000 tons—having secured those terms. The freight rate of the largest vessel will be seen to be the great sum of 20,000*l.* for a single voyage. A freight rate of 2*l.* 17s. 6d. per ton has also been conceded for a voyage from Cardiff to Bordeaux, and 3*l.* per ton is to be paid in the case of a voyage from Cardiff to Barcelona; the rate to Marseilles remains at 5*l.* per ton. Barcelona freights were about 8s. per ton before the war, and freights to other places were proportionate.—The Rhondda Tramways Company does not give its shareholders a dividend for the past year, but carries forward 5577*l.*, 3000*l.* being set apart for reserves and renewals. Delay in reopening a railless traction section was due solely to current scarcity of labour; during the short time the railless section was in operation the receipts on the tramways from Tonypandy to Williamstown were practically doubled.—The Bennett Steamship Company has announced a dividend of 6 per cent. with a bonus of 14 per cent., 3000*l.* is at the same time placed in reserve, while 15,000*l.* is allocated to the maintenance, renewal, and insurance fund, 23,944*l.* being finally carried forward, subject to excess profits duty and income tax.—Heavy orders for smalls are stated to have been placed for French and Italian railways; these orders are reported to exceed 200,000 tons; the prices to be paid range between 12s. and 18s. per ton, according to quality; and deliveries are to be made during the balance of the present now well-advanced year.—Messrs. Harries Brothers, Swansea, have acquired two more ships, of 2800 tons each, they are known at present as the Hooton and the Melton.—Tin-plates have been making 31s. per box at Swansea. A current feature of the trade is the large number of inquiries which have been received, many of them on foreign account. There is a movement in the trade to speed up the mills, so that full time shall be worked all round.

RAZORS FOR THE ARMY.—Mr. W. H. Ellis, the Master Cutler, Sheffield, has collected for the use of the troops 160,000 razors, of which 135,000 have been sent forward, after having been put in order by the staff of workmen which had been organised at the Cutlers' Hall. He has been asked by Lord Kitchener to continue his efforts, as the equipping of such a large number of men with satisfactory razors still remains an enormous task. He therefore desires that spare razors should be sent to him at the Cutlers' Hall, Sheffield.

STANDARD ACCUMULATORS FOR ELECTRIC VEHICLES.—The Electric Vehicle Committee informs us that in the recent announcement (see page 240 of our issue of March 10) relative to standardised over-all sizes for lead-plate batteries, it should have been stated that the over-all sizes agreed upon by the members of the Accumulator Manufacturers' Section of the B.E.A.M.A. are the maximum sizes, the intention being that the dimensions will cover any maker's cells containing each the same number of plates. This has been done in order that vehicle-makers may so construct the battery-boxes on vehicles that cells of a specified number of plates of any make may be fitted.

CONTROLLING MARINE ENGINES FROM THE BRIDGE.



THE s.s. Oura Maru, salvage vessel, belonging to the Mitsu Bishi Company, Japan, of 700 gross tons, with triple-expansion engines, has been fitted with apparatus by which the throttle-valve and the links can be controlled by the captain on the bridge without the assistance of the engineer. The apparatus is the invention of Mr. K. Ito, of the Mitsu Bishi Company. On the trials it was found that from 12 to 15 seconds' interval elapsed between the first movement given to the controller-handle on the bridge until the engines were changed from full speed ahead to full speed astern, against 25 to 30 seconds required when communication was effected by the telegraph to the engineer in the engine-room. There are two independent circuits, one for controlling the throttle-valve and the other for controlling the reversing gear by means of links.

The apparatus for controlling the throttle-valve is shown in Figs. 1 to 5 and Fig. 9, annexed. It will be seen that it is quite simple. The motion is derived from an electric motor, and this operates, by means of a worm and worm-wheel and a pair of bevel-wheels, the existing spindle by which the valve can be opened and closed by the engineer with the aid of a hand-wheel. The upper end of the spindle is screwed and works in and out of a long nut. When the operation is effected by the engineer, he rotates the spindle by a hand-wheel, and it moves endwise either upwards or downwards, according to the direction of motion. When the operation is effected by means of the motor, the nut, which is practically an extension of one of the bevel-wheels, is rotated and drives the spindle endwise in the desired direction. To enable this endwise motion to take place the hand-wheel is not rigidly connected to the spindle, but the two are joined by a coupling (Figs. 2 and 3) in which there is a cottar moving in a long slot, this slot being long enough to allow the spindle to move the required amount in either direction. A locking-handle (Figs. 4 and 5) is provided to fix the hand-wheel when the officer on the bridge takes charge of the operation.

The arrangements for setting over the links, both for reversing the engine and also for adjusting the expansion, are shown in Figs. 6 to 8 and Fig. 10. Figs. 6 to 8 are somewhat diagrammatic to enable the arrangement to be understood, while Fig. 10 is a photograph taken on the ship, and shows the motor on the engine-room floor, and not above, as in Fig. 6. The electric motor (Fig. 6) drives, through a worm and worm-wheel and a pair of bevel-wheels, a vertical shaft, at the lower end of which is a screw-wheel gearing on to a similar wheel (Fig. 8) situated on the crank-shaft of the existing steam turning-gear between the crank and the ordinary hand-wheel. In addition there is a brake on the hand-wheel which is pulled off by an electro-magnet when the current is turned on to the motor, and which automatically returns into engagement as soon as the current is cut off, and thus maintains the links in a position to which they have been adjusted. In other respects the reversing-gear follows the usual design. When it has to be operated by hand, the screw-wheel on the crank-shaft is uncoupled. It has no key, but there is on the one face of it a conical recess, which fits up against a conical shoulder on the crank-shaft (Fig. 6), and, by means of a hand-nut on the face of the hand-wheel, the two cones can be forced into engagement when the manipulation is to be effected by the electric motor. When hand-work is resorted to, the nut is slacked back, and the shaft can revolve under the influence of the hand-wheel inside the screw-wheel without affecting it.

This apparatus was described by Mr. Ito in a paper recently read before the Japanese Society of Naval Architects. At the same time he called attention to two previous apparatus for the same purpose—one fitted to the United States collier Neptune, and described in the Journal of the American Society of Naval Engineers for September, 1912, the other, on Mr. Alex. Esplen's system, fitted on the twin-screw steamer La Negra, and described in the *Shipping and Shipbuilding Record* for February, 1915. He also described an arrangement for controlling steam-turbines, but this has not been yet constructed.

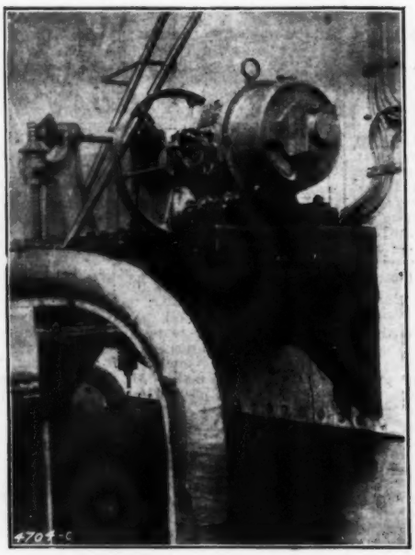


FIG. 9.

FIG. 10.

THE RANGOON RIVER TRAINING WORKS.

SIR GEORGE CUNNINGHAM BUCHANAN, C.I.E., M. INST. C.E., ENGINEER.

(*For Description, see Page* 299.)

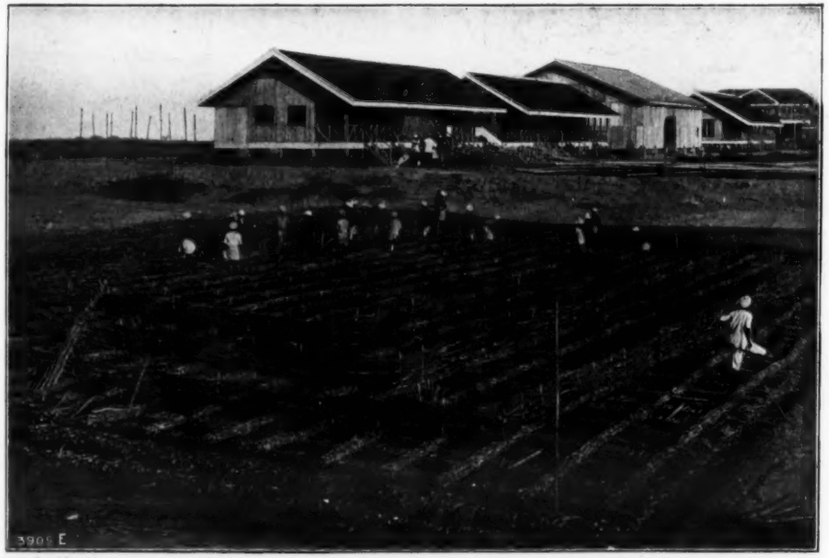


FIG. 3. A COMPLETED MATTRESS FOR WALL FOUNDATION.

FIG. 4. A MATTRESS BEING SUNK

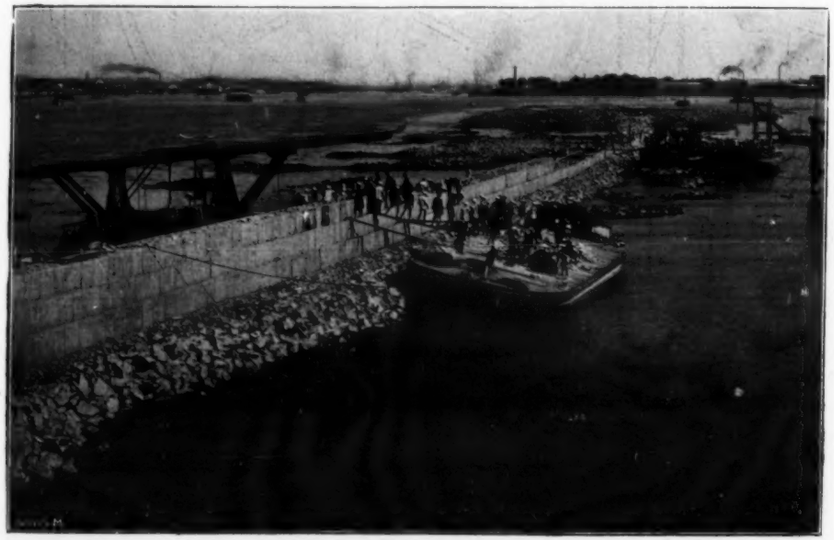


FIG. 5. SUPERSTRUCTURE IN COURSE OF ERECTION ON RUBBLE WALL.

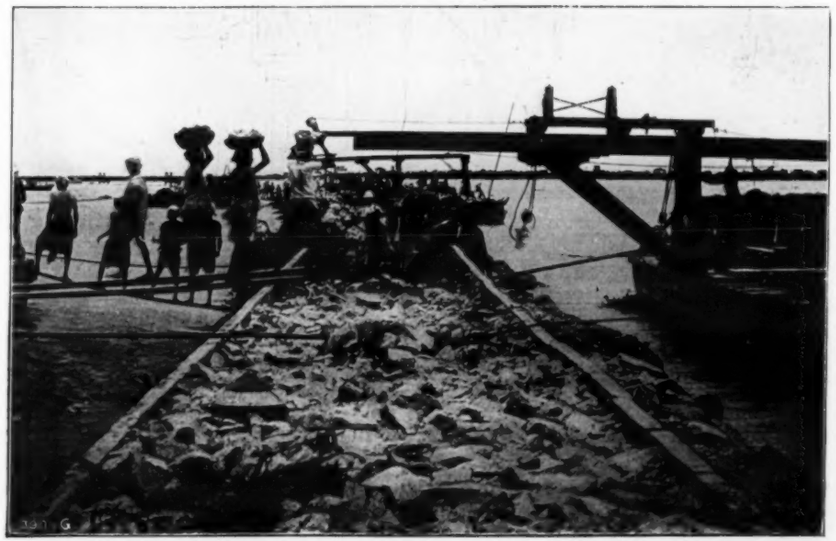


FIG. 6. FILLING SUPERSTRUCTURE WITH STONE RUBBLE.

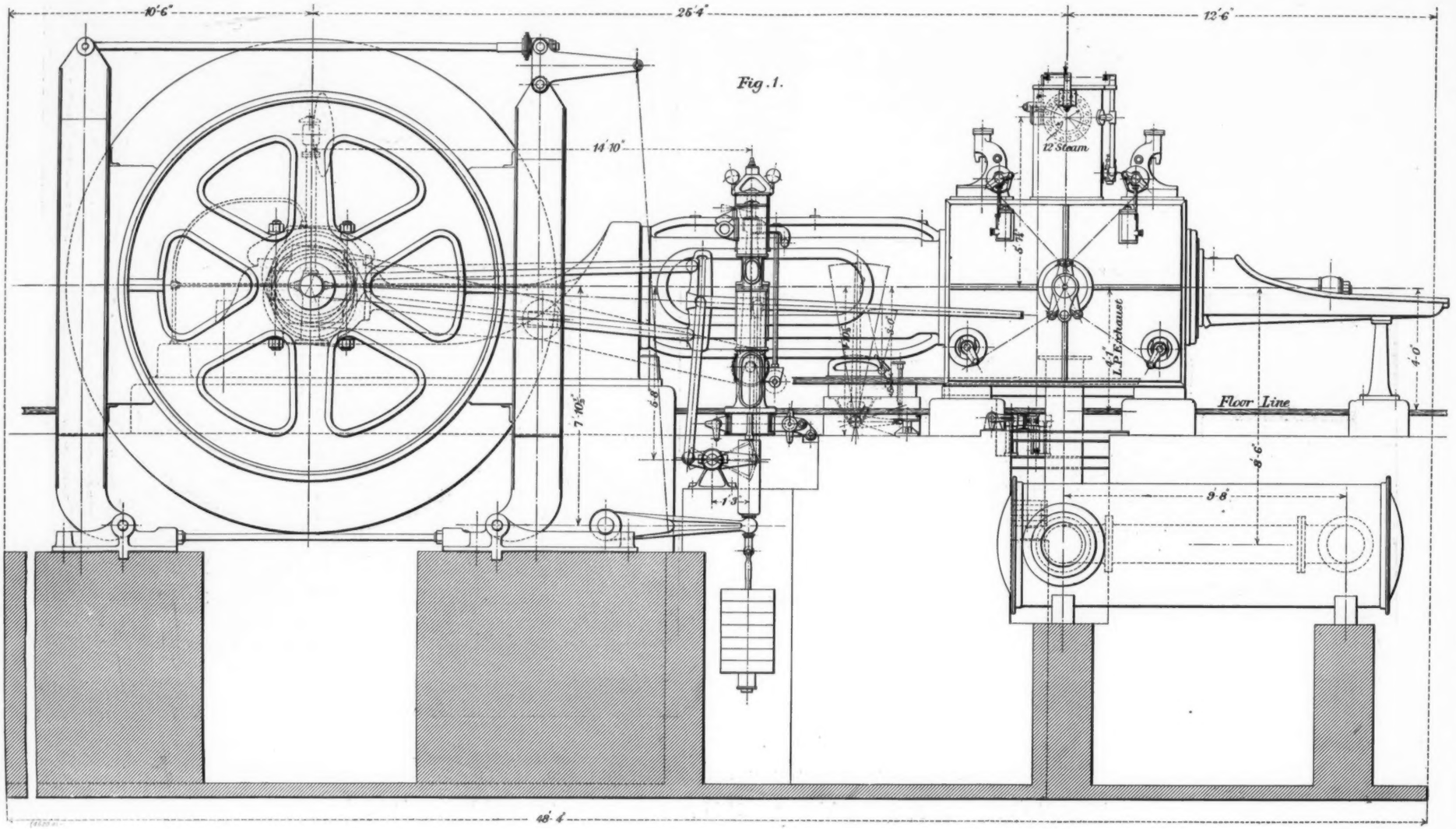
(*To Face Page* 298.)

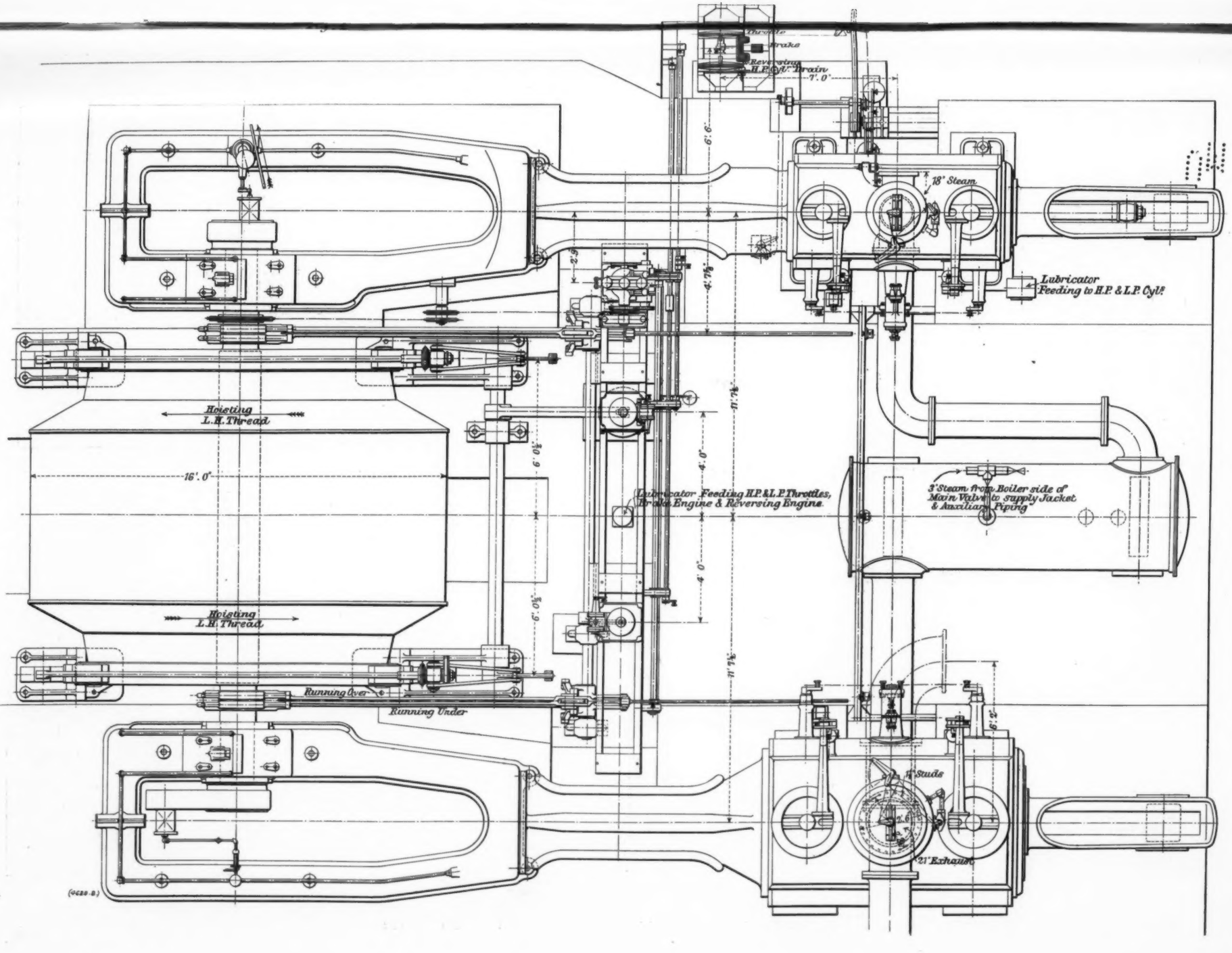
CROSS-COMPOUND WINDING-ENGINES FOR THE CHISLET COLLIERY, NEAR CANTERBURY.

CONSTRUCTED BY MESSRS. FRASER AND CHALMERS, LIMITED, ENGINEERS, ERITH.

(*For Notice, see Page* 299.)

Fig. 1.




Throttle
Brake
Reversing H.P. Cyl. Drain
7'. 0"
6'. 6"
18" Steam
Lubricator Feeding to H.P. & L.P. Cyls.
2'. 3"
4'. 7½"
11'. 7½"
Hoisting L.H. Thread
16'. 0"
9'. 0½"
4'. 0"
Lubricator Feeding H.P. & L.P. Throttles, Brake Engine & Reversing Engine.
3" Steam from Boiler side of Main Valve to supply Jacket & Auxiliary Piping
Hoisting L.H. Thread
6'. 0½"
Running Over
Running Under
6'. 2"
1" Studs
21" Exhaust
(9220-B.)

THE RANGOON RIVER TRAINING WORKS.

SIR GEORGE CUNNINGHAM BUCHANAN, C.I.E., M. INST. C.E., ENGINEER.

(*For Description, see Page* 299.)

FIG. 7. COMPLETED SUPERSTRUCTURE, 9 FT. HIGH.

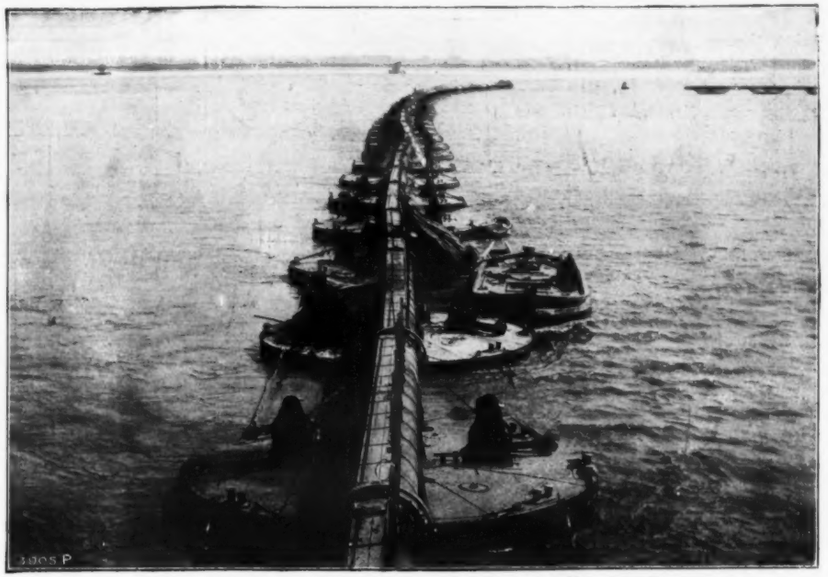


FIG. 8. 42-IN. PIPE-LINE DISCHARGE OF THE DREDGER "PELICAN."

FIG. 9. GENERAL VIEW OF THE COMPLETED WALL, LOOKING EAST.

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Advertisements intended for insertion in the current week's issue must be delivered not later than 5 p.m. on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than 1 p.m. on Tuesday in each week.

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Thin paper copies	£1	11	6 ($7.65)
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Foreign and Colonial subscribers receiving incomplete copies through newsagents are requested to communicate the fact to the Publisher, together with the agent's name and address.

All accounts are payable to "ENGINEERING," LIMITED. Cheques should be crossed "Union of London and Smith's Bank, Limited, Charing Cross Branch." Post-Office Orders should be made payable at Bedford-street, Strand, W.C.

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We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.

TELEPHONE NUMBERS—3663 and 8596 GERRARD.

S.S. "PERSIA" AND S.S. "MALOJA."

The Publisher desires to notify subscribers to "ENGINEERING" in the East who did not receive their copies of "ENGINEERING" of the issues of December 17, 1915, and February 25, 1916, that they may have gone down with the mails in the S.S. "Persia" and S.S. "Maloja." A few copies are still in stock of each of these issues, and may be secured at the ordinary rates, plus postage.

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With One Two-Page Plate of the RANGOON RIVER TRAINING WORKS, and Two One-Page Plates of the CROSS-COMPOUND WINDING-ENGINES FOR THE CHISLET COLLIERY, NEAR CANTERBURY.

NOTICES OF MEETINGS.

THE ROYAL SOCIETY OF ARTS.—Monday, April 3, at 4.30 p.m. Fothergill lecture. "Surveying: Past and Present," by Mr. E. A. Reeves, F.R.A.S., F.R.G.S., Map Curator and Instructor in Surveying to the Royal Geographical Society (Lecture II.). Wednesday, April 5, at 4.30 p.m. Ordinary meeting. "Painting by Dipping, Spraying, and other Mechanical Means," by Mr. Arthur Seymour Jennings, F.I.B.D., Examiner in Painter's and Decorator's Work to the City and Guilds of London Institute.

THE SOCIETY OF ENGINEERS (INCORPORATED).—Monday, April 3, at Caxton Hall, Westminster, S.W., at 5.30 p.m. A paper entitled "Modern Coal and Coke-Handling Machinery, as Used in the Manufacture of Gas," will be read by Mr. J. E. Lister, Wh.Ex., A.M.I.C.E., A.M.I.M.E.

THE RÖNTGEN SOCIETY.—Tuesday, April 4. General meeting, at 8.15 p.m., at the Institution of Electrical Engineers, Victoria Embankment, W.C. The following papers will be read:—Mr. P. J. Neate will describe and demonstrate a Chronograph constructed to work with the Electroscope; Mr. B. H. Morphy and Mr. S. R. Mullard will present a paper on "The Enclosed Tungsten Arc as a Source of Ultra-Violet Light;" Mr. E. Schall, B.Sc., will read a paper on "Experiments with a Coolidge Tube;" Mr. H. E. Donnithorne will read a paper on "A New Modification of the Ionisation Method of Measuring X-Rays." There will be an Exhibition of Plates showing "Experiments with the Coolidge Tube in Radiography," conducted by Members of the Staff in the Radiographic Department at the Cancer Hospital.

THE INSTITUTION OF CIVIL ENGINEERS.—Tuesday, April 4, at 5.30 p.m. Paper to be further discussed:—"The Rangoon River-Training Works," by Sir George Cunningham Buchanan, C.I.E., M. Inst. C.E. Paper to be submitted for discussion: "The Present Conditions of Arterial Drainage in Some English Rivers," by Mr. Richard Fuge Grantham, M. Inst. C.E.

ASSOCIATION OF SUPERVISING ELECTRICIANS.—Tuesday, April 4, at 7.15 p.m., at the St. Bride's Institute, Bride-lane, E.C. A paper will be read on "Alternate-Current Motors," by Mr. H. C. E. Jacoby.

THE INSTITUTE OF SANITARY ENGINEERS.—Wednesday, April 5, at Caxton Hall, Caxton-street, Westminster. Subject:—"Planning for a Manufacturing Town of 50,000 Inhabitants," Fellowship Thesis by Mr. Andre Le Marchand. Mr. H. Percy Boulnois (Past-President, Chairman of the Board of Examiners) will take the chair at 7 p.m. Discussion to follow.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, April 7, at 5.30 p.m. A discourse will be delivered by Mr. William Samuel Lilly, M.A., LL.M., Hon. Fellow of Peterhouse, Cambridge. The subject is "A Plea for War." Afternoon lectures next week at 3 o'clock. Tuesday, April 4. Professor F. Keeble, M.A., Sc.D., F.R.S., Director, Royal Horticultural Society's Gardens, Wisley, on "Modern Horticulture: Growing Time and Seed Time (Internal Rhythm)" (Lecture II.). Thursday, April 6. Dr. W. H. Hadow, M.A., Hon. D.Mus., Principal, Armstrong College, Newcastle, on "English Music in the Tudor Period: Secular Part Music" (Lecture II.). Saturday, April 8. Professor Sir J. J. Thomson, O.M., LL.D., D.Sc., Pres. R.S., Professor of Natural Philosophy, Royal Institution, on "Radiations from Atoms and Electrons" (Lecture V.).

THE NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—Friday, April 7, at 7.30 p.m., in the Lecture Theatre of the Literary and Philosophical Society, Newcastle-on-Tyne. The following paper will be read, and, time permitting, discussed:—"The Business Side of Science: Its Part in the Coming Economic Crisis," by Mr. T. C. Elder, of the British Electrical and Allied Manufacturers' Association.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper, and of the consequent shortage of supplies, readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk. Owing to the scarcity of paper it will be impossible in future fully to provide for a chance demand for this Journal.

ENGINEERING.

FRIDAY, MARCH 31, 1916.

THE RAILWAY-WAGON PROBLEM.

MANY engineering firms have in recent months experienced difficulties in obtaining supplies of railway wagons, and therefore they are directly interested in what has become known as the railway-wagon problem. Goods and mineral rolling-stock is divided into two categories—privately-owned and company-owned. The former, which represent the survival of the original conception of railways as lines upon which traders might place their own vehicles, are now practically confined to the conveyance of mineral, or Class A, traffic. They are hauled from the collieries to the ports or other places of destination and are returned empty to the pits. Railway-owned wagons are used for all classes of merchandise traffic, and when sent from the owning company's system to another line they have to be returned empty to the owning company, unless traffic is available for back loading to or in the direction of the "home" line. The problem is to reduce the haulage of empty stock to minimum proportions, and now that railways are under Government control it has become a point of criticism that wagons should not be used in common by all railway companies, thereby reducing empty haulage, and consequently increasing the availability of the stock.

The Coal-Mining Organisation Committee is responsible for a definite expression of opinion that the pooling of all railway wagons would save time in shunting, while generally facilitating the transportation of coal, and they have recommended that the Railway Executive Committee should prepare a scheme of pooling suitable to the different districts, and obtain for it the approval of the coal-owners. This proposal, however, has been the subject of the strongest opposition by the owners of private coal-wagons, and there would appear to be little probability of its realisation. Broadly stated, the objection to the surrender of such wagons is based on the fact that some owners are better provided with stock than others, and therefore they naturally object to surrender the advantage which they have over firms which are less well equipped. Others urge that their wagons have been built to meet the special requirements of their trade, such as the provision of end doors to admit of coal being expéditiously tipped, or drop-bottom doors for discharging at coal-staiths. Then there is the opposition of wagon-building and hiring companies, who foresee the disruption of their business. Even more cogent reasons for maintaining present arrangements are to be found in the fact that coal-wagons are really unsuitable for the conveyance of general merchandise, while in any event there would be little or no traffic for conveyance to the colliery districts, other than pit-props, which even now are frequently loaded in empty coal-trucks.

As regards railway companies' wagons, the case for common user is certainly much stronger, although there is much divergence of opinion as to whether the results are likely to be so appreciable as the advocates of pooling represent. Among those who press for a change are the Port and Transit Executive Committee, whose members are understood to believe that common user of wagons would have a material effect in relieving congestion at ports and harbours. In ordinary circumstances there would obviously be reluctance on the part of companies which are well provided with wagons to pool their stock with others which have not maintained so good or efficient a supply; but now that the railways are under Government control this does not apply. Indeed, it may be recalled that one reason assigned for the taking over of the lines was that "the railways, locomotives, rolling-stock, and staff, shall be used as one complete unit in the best interests of the State."

We surmise that the greatest difficulty is in arranging a system of rolling-stock control applicable to a general pool of railway companies' wagons. Each railway now arranges the distribution of its own stock, and, under the regulations of the Railway Clearing House, wagons that are loaded from one line to another have to be promptly returned. It is represented as being undesirable to alter a system that has worked tolerably well for one of which the results are problematical. Moreover, it must be borne in mind that the flow of traffic can never be equal. There must be many ports and manufacturing centres from which a greater volume of traffic is dispatched than is received by railway. The only possible means of providing an adequate supply of wagons for such places is to keep up a constant supply of empties, and we have no reason to think that in doing so the railways incur a greater amount of empty haulage than can possibly be avoided. Under any system of wagon distribution, therefore, there must be a certain amount of unremunerative train-mileage, and the question at issue is whether it would be less under a general pooling arrangement, or some other alternative to that in which each railway is a self-contained unit. In considering this proposition it is a feature that there has been in operation for many years an understanding between all railway companies for securing the loading on their return journey of as many "foreign" wagons as possible. Thus, wagons received by one company from another, and which have to be promptly returned, may be loaded with traffic to the owning company's railway, to stations beyond the owning company's railway, or to stations *en route* thereto. If, therefore, there is any traffic for conveyance, the wagons are loaded. If there is no traffic, it may be premised that the wagons would have to be hauled light for a certain distance, no matter what might be the system of distribution.

We think, however, that a system of common user of wagons must necessarily tend to reduce empty haulage and shunting out of empty vehicles. For example, there can be no doubt that the Great Western Railway wagons are much more economi-

(To Face Page 299.)

cally used over the whole of that company's system as it now exists than would be the case if the many once independent lines that form the present undertaking were treated as self-contained units. Similarly, we have no doubt that the recent decision of the Great Central, Great Eastern, and Great Northern Companies to use their rolling-stock in common is having good results. We think, therefore, that the solution of the problem is to be found in this direction. We shall certainly watch with great interest the pooling arrangement announced yesterday, by which the high-sided wagons of five great companies are, with certain exceptions, to be treated in common, as set forth in the circular we publish on page 309. If there could be brought about a grouping of the railways for the purpose of common user of rolling-stock, it would probably achieve more immediate and better results than an all-embracing arrangement that would involve the introduction of elaborate machinery of control. Having reduced the number of what may be termed wagon-distribution areas by a grouping of the companies, experience would be obtained which would be of the greatest value in determining the advantage or disadvantage of the system, and therefore the desirability of going a step further. On the result it might be found to be advantageous to set up a system, such as the German State Railway-Wagon Union, under which rolling-stock would be used in common on all the railways of Great Britain, while each company's responsibilities for providing and maintaining an adequate quota would be clearly defined.

EARTH TREMORS IN THE RAND.

SINCE 1907 numerous earthshakes have been felt in Johannesburg and elsewhere in the Rand. As they increased in frequency and strength, and gave rise in some quarters to apprehensions that the future of the whole mining area might be endangered, the Government last June appointed a committee of inquiry, consisting of Mr. R. N. Kotze, Government Mining Engineer (chairman), Mr. R. T. A. Innes, Union Astronomer, and Mr. D. Wilkinson, consulting engineer. The Committee have now presented their report, a full abstract of which is given in the *Cape Times* for February 10.

The shocks are described as consisting practically of a single sharp vibration, so that the sensation is similar to that produced by the sudden fall of a heavy body on the ground. On the surface, the shocks are sometimes of considerable strength, resulting in cracks in the walls of houses, the occasional fall of loose articles, and the rattling of windows. The underground effects are more serious, there being at times loss of life and damage to the mines. Persons are killed and injured by the fall of masses of rock, and shafts and other openings are closed up or otherwise damaged by the crushing in of the adjacent strata. Notwithstanding the intensity of the shocks, the area over which they are felt is small, the shock being felt only occasionally as far as seven miles from the centre of the area.

This, of course, points to a very slight depth of origin, and there can be no doubt that the Committee are right in ascribing the shocks to mining operations, and not to natural causes. The removal of the reef over large areas leaves the weight of the superincumbent mass, which may be 1000 ft. or more in thickness, to be supported by the unexcavated pillars. The pillars in consequence are crushed, and the crushing, when it takes place suddenly, gives rise to the strongest of the shocks observed. The severest shock yet recorded occurred on September 28 last, and this was found to be coincident with a serious shattering of the shaft pillar in the Village Main Reef Mine at a depth of about 1300 ft. Some of the minor shocks are attributed to the fracture of the strata overlying the excavated areas or to the settling of the strata into and over the excavations.

The Committee anticipate that still severer shocks may yet be experienced, but they hold that their violence will not be sufficient to justify the fear of any disastrous effects. With this conclusion all who have had any experience in studying similar earthshakes will entirely agree.

For the prevention or mitigation of further shocks the Committee recommend the removal of existing pillars when they are too weak to withstand the pressure to which they are subjected, and the substitution of sand-filling or other substantial form of packing. When the pillars cannot be removed, the disastrous effects of their bursting may be diminished by sand-filling in the adjacent areas, though it is not to be expected that this will, as a rule, relieve the pressure sufficiently to prevent the burst. In case of new shafts the pillars should be made much larger than has been the practice in the past, both for vertical and incline shafts. Drive-pillars and stope-pillars should be used as little as possible, and their places taken by artificial support.

Except for their much greater intensity, the Rand tremors resemble very closely the earthshakes that are felt from time to time in the mining districts of this country, and especially in those of the Rhondda Valley, various parts of Cornwall, and the neighbourhood of Pendleton, in Lancashire. The British earthshakes fall short of, though they sometimes approach, a destructive degree of strength. The shock consists of a single prominent vibration, occasionally followed by a brief tremor. The area disturbed by them is never more than a few miles in diameter. They differ from the Rand tremors chiefly in their close connection with adjoining faults. The disturbed areas, when they deviate from circularity, are elongated in the direction of the fault, and their centres lie a short distance on the down-throw side of the fault-line. They are obviously due to small slips or creeps along the fault, but as they occur at so slight a depth, the slips must be precipitated by mining operations, such as the withdrawal of the coal right up to the fault or by the pumping of water from the strata adjoining it.*

RADIATIONS FROM ATOMS AND ELECTRONS.

SIR J. J. THOMSON, O.M., P.R.S., delivered on Saturday afternoon last the third lecture of his course on the above subject at the Royal Institution.

In opening his discourse he said that on the present occasion he wished to consider a comparatively simple case—viz., the emission of light from certain substances at the ordinary temperature of the room, even when these substances were not exposed to electrical or other disburbances. Such bodies were said to phosphoresce. Prominent amongst them was luminous paint. The basis of this was calcium sulphide, and its discovery was due to the alchemists, who produced it in the course of their search for some method of transforming base metals into gold. He would observe that there had been few greater stimuli to research than this idea of the possibility of transmuting baser metals into gold. This lure apart, there would have been practically hardly anything accomplished in the way of experimental research at the times in question; but where curiosity as to the truth of natural phenomena failed as adequate incentive, the desire for money and power proved effective. In the outcome, the result had been closely analogous to that in Æsop's fable, in which the dying farmer set his sons to dig up the garden in search of a buried treasure. The quest failed, but the result of the digging was an enormous crop of fruit. These researches of the alchemists were, he continued, quite interesting reading at the present time, leading into by-paths now largely left on one side.

Taking a case of test-tubes filled with different substances and exposing them for a few seconds to the light of an arc lamp, the lecturer showed that, after removal, the tubes phosphoresced strongly, giving out a light which, in different specimens, ranged from red to blue. Whilst these bodies were rendered active by exposure to light, it was, the lecturer proceeded, not every kind of light that was capable of acting as a stimulus, the effective portion lying in the ultra-violet end of the spectrum, where the wave-length was too short to affect the eye.

A characteristic feature, he said, of nearly all substances that phosphoresced to a marked extent was that they contained sulphur in some form or other, and of these sulphur compounds only one—viz., zinc sulphide — comprised less than three constituent elements. The colour of the light produced was, moreover, very sensitive to the nature of the metal combined with the zinc, and to the presence of small impurities. In fact, in each of the tubes shown, the characteristic colour was probably due to the presence of mere traces of some metal or other. These phosphorescent bodies were, in fact, solid solutions of some sulphides. They were made by taking a large quantity of one substance and adding to it a very small quantity of another. The mixture was dissolved and precipitated, thus producing a very intimate mixture of the two ingredients, which yielded results not to be obtained from mere mechanical admixtures of one component with the other. Some complex substance appeared to result from the mutual interaction of the two ingredients, and this was peculiarly susceptible to light.

These bodies had, he continued, been studied very completely by Lenard and Klatt, who had established some very interesting points throwing light on the way in which phosphorescence arose. They found that all the phosphorescent bodies produced with any one metal—copper, for example—were characterised by a peculiar system of bands in the spectrum. The position of these bands might shift slightly from specimen to specimen, but the system still preserved its characteristics sufficiently to enable the metal to be identified. In the case of copper, the light capable of acting as stimulus was confined to two narrow bands close together in the ultra-violet portion of the spectrum. The effect showed a sharp maximum at each band, but disappeared between them. Corresponding results were observed with other metals, and the bands were as characteristic of the metal as was the colour of the phosphorescence produced. It was found, moreover, that the metals which gave the brightest light had high valencies, such as III. or IV., and could therefore give rise to compounds of different types. It was further observed that the heavier metals were better than the lighter, manganese being the lightest with which success was attained.

There was, the lecturer proceeded, much evidence in support of the view that in these cases certain conditions must be fulfilled. In the first place, there must be a greedy absorption of light to supply the requisite energy, and this light must be derived from the neighbourhood of an absorption band. The energy, corresponding to the absorption, went to produce within the mixture some kind of chemical change by which certain complex compounds were transformed into a different, and less stable, type. The latter naturally tended to go back to the original form; but reversion proceeded slowly, and was accompanied by the phosphorescence.

It was known that the action of light on a substance tended to make it give out negative particles of electricity. Hence it might be supposed that the effect of the light absorbed by the substance was to take from one of the compounds present a negative particle, which would naturally try to settle on any electro-negative element present, such as sulphur, in which, accordingly, the expelled particle found a temporary home. The new arrangement was, however, not permanent, but the reversion took place slowly. Each negative particle, however, as it was shot out of the sulphur fell back to its original resting-place with considerable energy, and this energy was that responsible for the phosphorescence produced.

The complete process consisted accordingly of a storage of energy, in the first place, due to the action of the light in causing negative particles to shoot out from the substances acted on, the work necessary for this being provided by the energy of the light absorbed. In the second place, these particles lodged in the sulphur, their position in regard to their original location being equivalent to that of a stone raised high above the earth. Finally the particle fell back to its original position, giving up its energy, which was then radiated out as luminous vibrations.

By exposing the phosphorescent body after excitation to extreme cold, as by dipping it into liquid air, this return of the particles could be stopped. In preparing liquid air that morning for this experiment, there had been, the lecturer said, a very serious catastrophe, since the tremors of the engine had cut short the life of Sir James Dewar's soap-bubble, after an existence of thirty-seven days. Had he had any suspicion of the danger, he would have deferred the matter till the bubble had succumbed to old age.

By the action of extreme cold it was, he continued, possible to suspend indefinitely the transformation

* C. Davison, (1) "On Earthshakes in Mining Districts," *Geological Magazine*, vol. ii., 1905, pages 219 to 223; (2) "The Pendleton Earthshake of November 25, 1905," *Geological Magazine*, vol. iii., 1906, pages 171 to 176.

into phosphorescence of the potential energy due to the lodgment of the displaced particle in the sulphur. Light could thus, as it were, be "put into cold storage," since the substance, on warming up again, would show its normal phosphorescence. In the foregoing case the production of phosphorescence was stopped by the extreme cold. With some bodies, however, the return of the displaced particle was so quick that under ordinary conditions no phosphorescence was visible after excitation by light. By keeping these bodies in liquid air during the process of excitation, the return could, however, be made slow enough for the bodies visibly to phosphoresce. This was the case, the lecturer showed, with an ordinary paraffin candle and with an egg-shell, both of which, treated as stated, continued to phosphoresce for some time after removal from the exciting light and the liquid air.

Light, he continued, provided one means of producing the phosphorescent effect, but there were others, though he had no doubt but that the mechanism involved was the same in all. Thus phosphorescence could be produced by simply bombarding some bodies with cathode rays, in which case negative particles were driven into the substances in question. The general effect was thus much the same as that produced by the action of light on ordinary phosphorescent bodies. This production of phosphorescence by means of cathode rays, the lecturer showed with powdered Iceland spar, which, treated as stated, continued to glow with an orange-coloured light long after the bombardment ceased. A similar effect was shown with fluorspar, which was, the speaker said, one of the earliest bodies known to be phosphorescent. A detailed study of this phosphorescence of fluorspar had, he continued, been made by Mr. Morse, who found that on stimulating it with light of a definite wave-length the spectrum of the consequent phosphorescence comprised a whole series of sharp lines. Mr. Morse had used in some cases terminals of zinc for his discharge-tube, and in others aluminium terminals, and the consequent phosphorescent spectra showed a number of bright lines, which had, however, no relation either to the spectra of the metals used as terminals or to that of fluorine. If these results were confirmed, they would, the speaker said, form an important addition to the few cases known in which spectra consisting of bright sharp lines had been obtained from solid bodies.

A somewhat similar case was provided by didymium, which yielded a spectrum of quite definite lines, which differed from compound to compound. In the case of didymium there would seem to be a resemblance to the resonance spectra of mercury, sodium, and iodine, discovered by Professor R. W. Wood. In Morse's experiments the resonance lines obtained with aluminium terminals formed one series, whilst the use of zinc terminals gave another series.

Thermo-luminescence, a phenomenon shown by certain solid solutions, was, Sir Joseph proceeded, of the same character as the foregoing, but in this case the new body was so stable and the return so slow that in ordinary conditions no visible light was produced. The return could, however, be accelerated by heating the body, in which case the energy was liberated at a rate sufficient to affect the eye. Taking a solid solution of manganese sulphate in calcium sulphate, the lecturer bombarded it with cathode rays, and showed that there was no sign of phosphorescence when the rays were cut off. On slightly warming it, however, it glowed brightly. In this case, he said, the new system formed by the action of the rays was so stable that the chemical reversion was not rapid enough to yield light unless it was accelerated by raising the temperature. The case was, in fact, quite analogous to that in which a body naturally phosphorescent was kept in liquid air, since the luminescence of the mixed sulphates could be developed a week after the original excitation.

It was not only with solids that luminescence was observed, but gases also could be made to phosphoresce. This the lecturer showed by inserting in a coil, traversed by an alternating current, a bulb containing pure oxygen at so low a pressure as to be conductive. The bulb, he stated, formed a secondary to the primary coil, and as the current passed through the latter the induced current in the bulb made the oxygen luminous, and this luminosity was retained for an appreciable time after the bulb was removed from the exciting coil. This phosphorescence, he proceeded, arose because the excitation produced a modification of the oxygen, which gradually reverted to its original state when the bulb was removed, and in thus going back gave out light. The lecturer further showed that the rapidity of this reversion was greatly increased if the bulb were heated, as the luminescence then ceased almost instantly. A similar glow could, he showed, be obtained with pure nitrogen, a discovery due to Professor Strutt, thus proving that changes of the character in question could be obtained in the case of gases as well as in that of solids. With liquids, on the other hand, fluorescence was more common than phosphorescence, but the distinction between the two phenomena was a matter of time, rather than a difference in action. "Phosphorescence" was the term used when the light lasted long enough after the excitation ceased for the light to be visible to the eye; but if the time of reversion was so short that the light was visible only so long as the excitation lasted, the phenomenon was known as "fluorescence." So far as was known, however, the effects were exactly the same in kind. Light fell on the fluorescing body and produced something else not so stable, which, in going back to its original condition, gave out light of a different wave-length from that which had acted on it as a stimulus. Most cases of fluorescence followed Stokes's law, according to which the light given out was always of greater wave-length than the exciting light. Some exceptions to this law were now known, in particular the resonance spectra discovered by Professor Wood.

Chemists had paid marked attention to the connection between chemical composition and the property of fluorescence, the matter being of interest in connection with dyes. The conditions necessary for fluorescence were that the body should be able to absorb energy from the light, and it must accordingly possess strong absorption bands. Its constitution must be complicated, so that new modifications might be readily formed, and these modifications must not be very stable, so that they might be able to revert readily to their original form. Certain theories had been advanced as to the kind of rings which best lent themselves to this kind of change. The subject had, however, been mainly studied in connection with dyes, where it was essential that the fluorescence must lie within the visible part of the spectrum, and this circumstance had, perhaps, hampered the formulation of a satisfactory theory. Simpler ideas might, perhaps, have been arrived at had more study been given to the cases in which the fluorescence lay in the ultra-violet, instead of imposing the condition that the incident ultra-violet light must produce a fluorescence of sufficiently long wave-length to affect the eye.

For his own part, Sir J. J. Thomson stated, he thought that a certain distinction between the various organic compounds to which he had called attention on a previous occasion might have something to do with the question whether an organic compound was fluorescent or not. He had brought forward evidence to show that in certain of these compounds the individual atoms were electrically neutral, while in other compounds some of the atoms might have an excess of either positive or of negative electricity. Some radicals accordingly functioned as if uncharged, and others as charged compounds. The most evident effect of ultra-violet light was its property of dragging out particles of negative electricity, so that if it fell on an uncharged compound it might cause it to become charged—a condition which was not stable—and the potential energy represented by this charge was responsible for the light generated, as the original condition was reverted to. Hence fluorescence might possibly be due to an oscillation of a radical between a charged state and an uncharged one. The primary cause was thus to be sought in the action of the incident light in causing a negative particle to be ejected, and on reversion the energy absorbed in this process was turned into light of a definite wave-length.

There was much evidence to show that the energy expended in such transformations was greater the shorter the wave-length. To illustrate this, the lecturer placed an exhausted bulb in the primary coil of the apparatus, previously used to show the phosphorescence of oxygen, and showed that the ring of light produced within the bulb was bluish near its outer edge, where the electric force was greatest, and reddish at its inner edge, where the electric force was weaker. This experiment, he said, indicated that there was a very important connection between the energy put into a system and the kind of light emitted in consequence thereof. Planck's relation between the two, which had led to some very interesting results, was that the energy necessary to produce light of a particular kind was inversely proportional to the wave-length.

ORGANIC PRODUCTS IN EXPLOSIVES AND MEDICINES.

If the British manufacturer does not rapidly attain to a condition approaching perfection, it will not be for want of reproof and advice. Recently when Dr. Strahan discoursed at the Royal Institution he commented on the "happy-go-lucky" way in which even so plainly scientific a search as the search for coal is carried out in this country. Lecturing in the same place on the Thursdays of the two past weeks on "Organic Products Used as Propulsive and Explosive Agents," and on "Organic Products in Medicine," Professor H. E. Armstrong, F.R.S., censured manufacturers, the Government, and the public in general, not sparing the scientists, for not following up pioneer movements in this country, and for not allowing scientists to help, and the scientists in particular for not organising themselves. The historical line which he adopted made his argument all the more forcible.

In his first lecture, Dr. Armstrong pointed out that modern high explosives, instead of containing the nitrate of the old black powder in a merely mechanical mixture, were chemical compounds, nitro-derivatives or nitrates, produced by the nitrification of organic bodies (cellulose, glycerin, hydrocarbons from petroleum and coal-tar) with strong nitric acid, to which sulphuric acid was added for various reasons. Cooling was generally necessary to check the violence of the reaction. Gun-cotton was made from purified cotton, by treating it with a mixture of strong sulphuric and nitric acids, expressing the acid by centrifugal action, rapidly washing with water, and then boiling the mass with water; the pulp thus obtained was compressed. The modern method placed the cotton between perforated partitions and removed the acid by displacement. The manufacture of nitroglycerin (chemists prefer the name "glycerol" for glycerin) was, the lecturer said, equally simple; glycerol was soluble in water, the nitro-product was an oil not soluble in water. The nitrotoluol manufacture from the toluol proceeded in three stages, the resulting products being the mono-, di-, and trinitrotoluols. When the colourless toluol was mixed with the mixed acids it turned yellow, and the reaction evolved much heat, unless efficient cooling was applied. The mono-product was liquid; the preparation of the di-product, which was solid, generated little heat, and to obtain the tri-product heating had to be applied. The ultimate T.N.T. was a crystalline cake melting at 80 deg. Cent.; this mass was poured into shells, some trinitrotoluol crystallised from alcohol was placed on the top of the mass, and a detonator and its primer were finally added. The whole nitrification was carried out in cast-iron vessels. Picric acid was trinitrophenol; the raw material, phenol or carbolic acid, was now made on a large scale in this country; Professor Armstrong showed an iron barrel full of the silky needle crystals. To make picric acid the two acids were used separately, the sulphuric acid first.

The lecturer, who was assisted by Mr. W. Robertson, demonstrated the manufacture of the three first-mentioned explosives, but not of picric acid. The energy and heat of the combustion of hydrogen and oxygen were, the lecturer said, important factors in the energy of explosives, in which the hydrogen was oxidised to water, the carbon to CO_2 or CO, while the nitrogen was generally liberated as such; some of the explosives contained too much oxygen, in which case some free oxygen would be liberated, some too little for complete combustion. Small volumes of solids suddenly broke up into enormous volumes of gases, and all the liberated gases would be at very high temperature, and thus all the more energetic. Chemically the so-called nitro-products were not all of similar constitution. Glycerol was a hydrate, $C_3H_5(OH)_3$, analogous to bismuth hydrate, $Bi(OH)_3$, and the nitroglycerin, $C_3H_5(NO_3)_3$, corresponded to bismuth nitrate. $Bi(NO_3)_3$, and contained an excess of oxygen. Cotton was $C_6H_{10}O_5$, gun-cotton $C_6H_7(NO_3)_3O_2$, also a nitrate, containing just enough oxygen for complete oxidation. Toluol was C_7H_8; the trinitrotoluol $C_7H_5(NO_2)_3$ was a real nitro-product, but contained only

sufficient oxygen to convert half of its carbon into CO, the other half escaping as carbon soot; the extraordinary violence of this explosive was probably due to the most intimate contact of the constituents in the closely-packed molecules. Similar considerations held for picric acid.

Having explained the reactions of these explosions, Dr. Armstrong dwelt on the close touch in which the Royal Institution had always been with explosives and with organic chemistry in general. Faraday had not only been a great electrician; he was also a chemist, and had been in constant correspondence with Schönbein, who discovered gun-cotton and its solubility (collodion) in 1845. Nitrification had been effected before that by Braconnet and Pelouze; but Schönbein had had theoretical reasons for using sulphuric acid in addition to nitric acid. Having fired guns with gun-cotton, Schönbein had come over to England (where he had been before) and to the Royal Institution to get his invention taken up; but he had to return, a sadly disappointed man, writing to Faraday of having gained nothing but an increased knowledge of the world and the annoyance of a not easily-ruffled temper. German authorities had also declined to try his gun-cotton, and the experiments in Austria were soon stopped by the explosion of a gun. A new movement had then started in Sweden, where Alfred Nobel manufactured nitroglycerin (discovered by A. Sobrero in 1846), absorbed the liquid by kieselguhr in 1863, and then combined it with gun-cotton in blasting gelatin. Already before that Frederick Abel and A. Nobel had worked and lectured on steel guns (instead of bronze guns), explosives, and shells in the Royal Institution; they then introduced smokeless powders, made of the new explosives. In 1889 Abel and Sir James Dewar took out patents, on behalf of the Government, for the manufacture of cordite, made by mixing and kneading one part of nitroglycerin with two of gun-cotton and some vaseline. The stability of that explosive in all climates had necessarily been questioned at first; but Dr. Armstrong showed some hanks of the first cordite made, lent by Sir James Dewar, which looked and burned like the modern product. The outcome of these researches had been that the manufacture of gun-cotton and nitroglycerin products had been brought to a high state of perfection in this country. But little attention had been paid to new high explosives, and though the Government had often been warned (the lecturer read one of his own letters from 1901 among others), the services of competent chemists had not been accepted for the control of the works, and a chemist had not been appointed on the Ordnance Board till the end of last year.

To introduce his second subject Dr. Armstrong had very briefly to outline the development of structural chemistry, and he did this with special regard to benzene and its history. Benzene was discovered by Faraday in 1828, in days when oil-gas (made by dropping oil into red-hot retorts) was supplied in cylinders as hydrogen, &c., were sold now. Faraday's name and formula for the new body, bicarburetted hydrogen, C_2H, appeared peculiar, but were quite justified; for the accepted atomic weight of carbon was then 6 (12 now), so that, on the modern notation, the percentage composition would be CH or C_6H_6 (as now written). Mitscherlich, obtaining the same body from benzoic acid, called it benzin, which Liebig changed into benzol, because the body was not of alkaline character; Laurent gave it the name phène (from its fluorescence), which survived in phenol (carbolic acid), &c.; chemists now preferred the name benzene. On Hofmann's suggestion (at the Royal College of Chemistry in Oxford-street), Mansfield further investigated the structure of hydrocarbons. Meanwhile structural chemistry had developed, chiefly owing to Frankland's suggestion of the atomic fixing power of elements, and Kekulé's work (at Bonn) on benzol derivatives. But benzene, behaving like a saturated hydrocarbon, though badly deficient in hydrogen apparently, proved altogether peculiar and different from the saturated and unsaturated compounds which could be traced back to CH_4 and a tetravalent carbon atom, until Kekulé proposed the ring or hexagon structure for the benzol molecule. That suggestion, with its novel wealth of possible isomeric ortho-, meta-, and para-compounds, had had a stupendous influence on the development of organic chemistry. Many of the new synthetically prepared medicines were benzol and coal-tar derivatives.

The first artificial drug, introduced by Liebreich in 1869, had been chloral, a body closely related to chloroform, and intended to be converted into chloroform in the blood. Then Crum-Brown and Fraser had shown that the alkaloids (strychnin, &c.) differed physiologically in their nerve action, as well as in their chemical constitution, from the organic bodies of the ammonia type to which they had been likened. Kolbe, in 1871, prepared salicylic acid, a specific against rheumatism; it was orthohydrobenzoic acid, and the meta- and para-compounds were therapeutically quite useless—why, was not understood, but medical men hardly understood rheumatism. Salol, acetyl salicylic acid or aspirin, which lowered the body temperature, acetanilide and phenacetin (of similar effect) were all related to salicylic acid. Antipyrin (Knorr, 1884, from aceto-acetic ether and phenyl hydrazine) had a very different structure. The local anæsthetic cocaine was derived from the indifferent eggonine by introducing CH_3 and $CO.C_6H_5$; of the now largely used novocaine, β-eucaine, and stovaine (the discoverer, Fourneau, had adopted the English equivalent of his name, stove) the latter two were pyridin derivatives. Adrenalin, which was produced in the very small suprarenal gland, and controlled the blood pressure in a marvellous way, was a complex benzol derivative, closely allied to tyrosin; the natural adrenalin was optically active, whilst the artificial adrenalin was inactive (containing both the dextro- and laevo-modification), and Dr. Armstrong suggested that active and inactive forms might fit into one another, like a model fits into its several templates. The atoxyl (against sleeping sickness) and salvarsan of Ehrlich were complex arsenic derivatives of benzol, one of the points being that, when arsenious acid was administered, 0.0038 gramme of arsenic was the safe limit, whilst in atoxyl and salvarsan doses of 0.14 and 0.18 gramme could be borne.

Dr. Armstrong exemplified by many more illustrations how systematic constitutional research had led to the attainment and accentuation of special effects, in remedies as in dyes. Anæsthetics, it was noteworthy, affected plants and the human system through their cells in similar ways. Much remained obscure, of course. It was not understood, *e.g.*, why the substitution of C_2H_5 for CH_3, *e.g.*, changed the physiological action of a compound; but the researches proceeded on definite lines. Dr. Armstrong showed a German trade catalogue, a bulky volume, dealing merely with one class of drugs, to indicate the nature of the work involved.

NOTE.

Development of Zeppelin Airships.

The fact that a Zeppelin airship was brought down by the French at Révigny, on February 21 last, will still be fresh in the minds of most of our readers. The airship, it will also be remembered, was hit at a height of about 2000 m. (6,500 ft.) and fell in flames, while engaged on an attempt to destroy the railways supplying Verdun, preparatory to the great German attack on that fortress. It is unfortunate, from a scientific point of view, that the airship was almost destroyed by fire, so that all the details of its construction could not be determined by our Allies. A considerable amount of information has, however, been obtained from the wreckage, and some of this information has been published in a recent article in *The Times* by M. Georges Prade. That the airship was one of the latest types may be inferred from the fact that its number was LZ 77, it being known that two airships delivered from the Zeppelin works in July, 1914, just prior to the outbreak of war, were numbered LZ 24 and LZ 25; it would thus appear that not less than fifty-two airships of the Zeppelin type have been constructed during the last eighteen months. The framework was too badly damaged for direct measurements to be made, but by an examination of the curvature of the main girders, and by calculation of the limiting stresses, it has been deduced that the length was 160 m. (525 ft.), and the capacity 30,000 cub. m. (1,060,000 cub. ft.). The metal used for the framework was aluminium with small percentages of copper and zinc. It is interesting to note that the shape differed from that of the earlier models in that the cylindrical, or nearly cylindrical, body, with rounded ends, was replaced by a torpedo-shaped body similar to those employed on the French and British airships; this would doubtless effect a considerable reduction in the air resistance. The airship was propelled by five Maybach water-cooled motors, each having six cylinders 160 mm. in diameter, with a stroke of 170 mm., and weighing about 9 cwt. These engines would each give from 180 to 200 horse-power, and would require about 14 gallons of petrol and two-thirds of a gallon of lubricating oil per hour; it was not possible to calculate the radius of action of the airship, owing to the fact that the oil and petrol-tanks were melted by the fire. Each engine drove a separate propeller, two of which were placed on each side of the body, while the fifth was mounted behind the rear car, and would thus not only increase the speed in a horizontal direction, but also enable the airship to rise more rapidly when using its elevating planes. As usual, the airship had two cars, or gondolas, carrying the engines, and connected by means of a central cabin, in which the pilots and gunners were stationed, and from this cabin a ladder led up through the body between two of the twenty ballonets to a platform on top. Two machine-guns were mounted on this platform, and two more were placed in each of the gondolas. No other guns were carried, and no trace of a searchlight could be found, though the airship was, of course, provided with wireless apparatus. The human remains found indicated that the crew numbered twenty-three, and this figure, it should be noticed, corresponds with the number seen by the captain of the trawler King Stephen on the airship L19, wrecked in the North Sea. The LZ 77 carried twenty bombs, weighing either 50 kg., 80 kg., or 100 kg. (110 lb., 176 lb., or 220 lb.) each, and having a total weight of 1500 kg. (nearly 1½ tons). Each bomb was suspended by a special form of hook, from which it could be released electrically by operating a push-button in the cabin. The following data of some of the earlier Zeppelin airships, when compared with the above particulars of the LZ 77, will show clearly the great development made in this type of aircraft during the last few years. The lengths of the 1912 and 1913 models were 141 m. (462 ft.) and 156 m. (512 ft.) respectively, and their diameters were 14.8 m. (48 ft. 6 in.) in both cases. Their respective capacities were 19.500 cub. m. (688,000 cub. ft.) and 22,000 cub. m. (776,000 cub. ft.), and they were both driven by three motors of the same type and dimensions as those given above, coupled to four propellers; the crews carried numbered eight and twelve men respectively. In the 1914 models four motors, each driving a separate propeller, were employed, and a crew of eighteen men was carried. These airships were 158 m. (518 ft.) in length and 16.58 m. (54 ft. 6 in.) in diameter, and their capacity was 27,000 cub. m. (952,000 cub. ft.).

THE INSTITUTE OF METALS.

The annual general meeting of the Institute of Metals was held in the Rooms of the Chemical Society, Burlington House, on Wednesday, the 29th inst., the chair being occupied during the preliminary proceedings by Vice-Admiral Sir Henry Oram, K.C.B., F.R.S., the retiring President.

Report of the Council.

The report of the Council showed that, in spite of the war, the membership of the society has been well maintained, the total number having risen from 626 at the end of 1913 to 645 at the end of 1914, and being 640 at the end of 1915. In the latter figures the names of 18 alien enemy members are not included. The small decrease during the past year is mainly in the student class, the numbers of which have fallen from 19 in 1913 to 10 at the present time. The Council have remitted the subscriptions of certain of the 55 members engaged on active service. The Council report that there have been frequent communications on technical matters between the Institute and the Ministry of Munitions. Four members are also members of the Admiralty Inventions Board, and another is serving on the Munitions Inventions Board. The Institute has also been invited to send suggestions to the Advisory Council on Scientific and Industrial Research.

A new constitution had, it was announced, been given to the Corrosion Committee, of which half the members will in future be appointed by certain Government departments and other public bodies or societies interested in this research. Admiral Oram, moreover, announced that an annual grant of 900*l.* towards this fund had been made by the Government.

The Birmingham local section, it was reported,

has had a successful session in spite of the war, the total number of members and associates being now eighty-five. The sales of the Journal of the Institute appear of late to have been stimulated by the war, a notable number having been recently required by the United States and Japan.

Sir J. J. Thomson and Sir William Crookes have been elected honorary members.

FINANCE.

The report of the Treasurer, Mr. A. E. Seaton, J.P., M.Inst.C.E., showed that the financial year started with a cash balance of 794*l*., and that this figure had risen to 955*l*. twelve months later. The special "Corrosion Fund" has in the same period been increased from 309*l*. to 353*l*. Subscriptions have, however, fallen from 1420*l*. to 1335*l*., but expenses were reduced by the decision to hold no annual dinner nor ordinary autumn meeting.

THE NEW COUNCIL.

The results of the ballot for the new Council were then announced as follow:—President, Dr. G. T. Beilby, F.R.S.; Vice-Presidents, Mr. G. A. Boeddicker, Professor H. C. H. Carpenter, Mr. J. T. Milton, Mr. L. Sumner, Sir K. T. Rose, and Professor T. Turner; Hon. Tres., Mr. A. E. Seaton; Members of Council, Messrs. W. H. Allen, L. Archbutt, G. Bean, Dr. Bengough, A. Cleghorn, J. Dewrance, G. Hughes, R. S. Hutton, W. M. Morrison, Mr. A. Philip, W. Rosenhain, W. Weir, Sir Robert Hadfield, Sir C. A. Parsons, and Sir Wm. Smith.

After a vote of thanks to the Council had been moved by Dr. R. Seligman, and seconded by Colonel N. T. Belaiew, Admiral Oram vacated the chair, which was then taken by Dr. Beilby, the new President. The vote of thanks to Admiral Oram was moved by Professor T. Turner, who said that in spite of the retiring President's very onerous labours on behalf of the Navy he had been most regular in his attendance at the Council meetings, where his advice had been most useful. Admiral Oram had also done much to bring in new members of a particularly desirable class. The speaker hoped that as Past-President his interest in the Institute would be retained.

The vote was seconded by Dr. W. Rosenhain, who said that the Institute had had a remarkable succession of presidents, and this tradition had been not merely maintained, but, if possible, raised still higher by the retiring President. In reply, Admiral Oram expressed the view that the proposer and seconder had overrated the services which he had been in a position to render.

THE PRESIDENTIAL ADDRESS.

Dr. Beilby then delivered his presidential address. He began by thanking the Institute for an honour which was unexpected and, he feared, hardly deserved. When the Council were good enough to suggest his election, he had felt bound to tell them that, in view of the great pressure which the war made on his time, he could not hope to give an address worthy of the occasion and the office. As matters stood he would have, therefore, to be brief; but perhaps if more fortunate times arrived during his term of office, it might be possible for him to extend and supplement the observations to be made that day. In passing, he might note that the Institute had now completed seven years of useful work, of activities, both manifold and sustained, and its record formed a complete justification of the establishment of an independent society devoted to the study of non-ferrous metals. One of the first instincts of a new president was to examine the record of past sessions. Statistical surveys appealed, however, to minds of a particular type only, so he would merely say that some 112 memoirs had appeared in their Proceedings. Of these, the larger proportion dealt with experimental researches directed to fundamental questions as to the physico-chemical properties and constitution of alloys. There appeared to be a great preponderance of such memoirs, the manufacturing aspect being, on the other hand, somewhat neglected. It was true that they could not have too much of papers devoted to the scientific side of the subject; but they might well have too few of an industrial character. The Council wished to make it clear to manufacturers that the Institute existed for their benefit, and that it had been the earnest wish of all that the help and resources of the Society should be used to the fullest possible extent.

Certain questions, he proceeded, had been very especially brought home by the war. Metal manufacturers had assumed that an ample supply of metals for all their needs would continue to be forthcoming; but these optimists had experienced a rude awakening. Whilst copper had not risen much above its normal price, zinc cost many times as much as formerly. He had originally intended to discuss this situation somewhat fully in his address, but the Society of Arts having offered the Le Neve Foster prize for memoirs on "Zinc, its Production and Industrial Application," the winning essay gave such an admirable *résumé* of the whole matter that he need not anticipate its publication.

One thing was clear—viz., that zinc-smelting on a large scale must be established in this country. We could procure the ores and we had the fireclay and the coal, and we also had the engineers and metallurgists for the work. In looking through the Transactions of the Institute, however, he had noted a remarkable dearth of papers on the production and smelting of zinc. There were but two, read respectively in 1909 and 1910, and both dealing with the filtration of zinc fumes. The subject was, nevertheless, of the greatest interest. The world's output of zinc ranked with that of lead and copper, the output of each being about one million tons per annum. Great Britain and her Colonies could easily be self-supporting in this regard, and he trusted that future volumes of the Proceedings of the Institute would deal with the successful smelting and calcining of this metal on a large scale. Magnesium was another metal of which the production in this country had been abandoned, and, indeed, it was commonly looked on rather as of chemical than of metallurgical interest. It was nevertheless of great value for the removal of gases from metals. It used to be made in this country from its chloride by reduction with sodium, but this manufacture had been abandoned on the development of the electrolytic process in Germany, from which country all needs were met prior to the war. Since the outbreak of hostilities, however, the speaker had been approached for aid in furnishing a new source of supply, and the process of reduction by sodium had accordingly been revived by a British firm, and the needs of the market had thus been met. Nevertheless magnesium was still regarded by British metallurgists as a curious rather than as a useful metal; but if it were manufactured on a large scale so as to be cheaply produced, it would, he believed, find many applications to the making of light alloys. This industry had been largely left in German hands, but the speaker suspected that we had not received their best products, and that a superior class of alloy was being used in German aircraft of which we had no knowledge. The early enthusiasm with which aluminium had been welcomed had been based on the belief that it would equal ordinary structural materials in physical and mechanical properties and maintain its advantage of lightness. In all regards but the latter the metal had proved disappointing, and this disappointment still, he thought, cast a reflected discredit on other light alloys. When the war was over this study of light alloys should be resolutely attacked, and chemical, thermal and micrographic data collected. The work should be organised on broad lines by a central authority, but this authority must not be employed to sterilise the whole scheme, discouraging individual workers. Most would agree that an organisation was apt to hinder pioneering work. In his own work he had himself made few real advances, but the number would have been fewer still if he had had to justify each intended new move to an independent authority. Psychologically there was little to distinguish the early stirrings in the mind of the inventor from similar stirrings in that of the crank. Afterwards, no doubt, it was easy enough, but every inventor, if honest with himself, recognised that only a few of his pioneering intentions received the final justification of the success which mainly served to differentiate him from the crank.

For work in which lightness and strength were of first importance materials must either be light intrinsically or must be strong, and so disposed by the designer as to make the most of this property. The designer, however, could not carry out his part satisfactorily unless he were fully informed as to the qualities of the materials available, and the influence on these of the processes by which they were worked into appropriate forms. The Institute might well play an important part in providing the necessary data, and the matter was the more pressing, as it would seem that aircraft might prove of service even in peace transport. Light alloys had to compete with other existing materials. On the one hand their rivals were iron, nickel, and copper, with specific gravities of from 7.5 up to 8.5. Woods, fibres, and other organic materials were also employed, and these had a specific gravity ranging from a little below to a little above unity. The specific gravity of the light alloys ranged from 1.75 to 5 or 6. The valuable mechanical properties of organic materials depended on the fact that the vital processes produced, in the first place, a variety of substances which had themselves valuable mechanical qualities, which were further enhanced by blending two or more, so as to supplement each other's deficiencies. In the third place, as the process of cell-building was carried on on a scale not far removed from that of the molecule, the resulting "texture" was very fine. This minuteness of the texture rendered the cohesive force of the molecules more available than in more massive and homogeneous aggregates. He had used the term "availability" to denote that portion of the total cohesive forces of the molecules which was available for holding them together. At the surface of a solid or liquid there was a region, many molecules thick, in which the cohesion was more powerful than it was at greater depths. Thus the strength of the two surfaces of a soap-film was much greater than that of the liquid between. If a mass of foam could be produced consisting entirely of bubbles, only a little greater in diameter than the range of the cohesive forces and with correspondingly thin walls, the mass would possess in a high degree the characteristics of a solid. In this case the increase of availability was secured by increasing the proportion of molecules in the surface layers. Unfortunately, the vital processes of cell-building could not be imitated in the workshop, and we could only accept gratefully the ready-made products of vital activity. Whether it would be possible to go further in applying these principles could not be predicted. Great strides had been made in the preparation of hard and enduring metals without it being recognised that the rigidity and tenacity of a material was wholly a matter of using advantageously the intrinsic cohesion of its own molecules. This principle was the foundation of all methods of hardening metals by alloying, chilling, or cold-working. He found no difficulty in picturing a metal made up of a mass of foam bubbles and films so small that an enormously great proportion of the total cohesion of the molecules would be available to increase the rigidity and tenacity of the mass, whilst the specific gravity need not exceed one-half of the usual value.

THE CORROSION COMMITTEE.

A vote of thanks to the President for his stimulating address was moved by Dr. H. C. H. Carpenter, who observed that he had been accustomed to regard former occupants of the chair either as manufacturers, users, or scientific investigators. Dr. Beilby was, however, qualified under all three heads. He was a manufacturer of the very important non-ferrous metal sodium, which was now used, not only for the reduction of magnesium, as explained in the address, but had also large applications in the extraction of gold. Dr. Beilby was, further, one of the most eminent of chemical engineers, indeed, a founder of the profession, and he had certainly done much also to advance and raise its status. The circumstances which led to Dr. Beilby's scientific investigations into the physical characteristics of metals were of great interest. He thought he was right in saying that they originated in the misbehaviour of metals when exposed to certain gases at a high temperature. Dr. Beilby had found that every metal, when exposed to the action of ammonia at a high temperature, gave trouble. The profound changes thereby produced in the structure of the metals had led to the foundation of the new theory as to the distinction between the amorphous and hard state as contrasted with the crystalline and soft. It was the difficulties he had met with in chemical engineering which had led Dr. Beilby to take up his studies on structure.

The vote was seconded by Mr. J. Dewrance, who said the zinc situation, to which the President had referred, would appear to all as a very serious matter. It had not, however, arisen from a lagging behind of the scientific men of this country. The difficulty was financial, and not scientific in

origin. German financiers had acquired the control of supplies throughout the whole world, and this caused the shortage. Had it paid to produce the metal here it would have been done. A personal experience might be of interest. Years ago the speaker's laboratory developed into a factory for the production of a certain metallic salt. The manufacture was next taken up by Germany, and from time to time he got full particulars of their methods and processes, which were throughout much inferior to his own. Finally, however, the Germans cut the prices below what it cost them to produce, and the speaker decided to close down his works. The next week prices were doubled, and the cost was now twelve times as much as formerly. It must not, therefore, be imagined that the responsibility for the shortages experienced lay with our scientific men, but, nevertheless, it was the duty of all to see that research was encouraged in this country.

THE COMMITTEE ON CORROSION.

Before calling on Mr. W. E. Gibbs to read an abstract of the Third Report of the Committee on Corrosion, Dr. Beilby expressed the Committee's appreciation of the unselfish way in which Dr. Bengough had relinquished his own work at the outbreak of the war, joining the Garrison Artillery, in which he had rapidly been promoted to the rank of captain. The thanks of the Committee were due to the Broughton Copper Company and to the Muntz Metal Company for supplying the tubes used in the investigation.

Mr. W. E. Gibbs said that, as would be seen, five different alloys had been tested. The composition of the phosphor-bronze and aluminium-copper tubes had, however, been omitted. The former contained 3.8 per cent. of zinc and 0.02 per cent. of phosphorus, whilst the other new alloy had 7.92 per cent. of aluminium, 0.25 per cent. of iron, and 0.13 per cent. of silicon. A description of the appearance of the test-pieces had been added in the report and should facilitate comparison with results observed later on. One novel point brought out in the new research was that the action of stagnant sea-water varied with the depth of immersion owing to corresponding variations in the air content. Dr. Bengough, immersing his specimens to a depth of 1 in., had found spots of oxychlorides on the upper surface. With the 3 in. immersion adopted by the speaker no such spots were developed. The most important point established was that the dezincification of the brasses in sea-water depended on three things—viz., the aeration, the dilution, and the CO_2 content. The experiments made with pure copper and pure zinc bore out the observations made on the two as alloyed. Aeration of the water in condensers arose from eddies at the mouth of the tubes. Just inside the tube-plate there was thus a "churning" point at which corrosion was marked, and especially in low-temperature tests.

It would appear that the solution of copper in sea-water depended very largely on the dissolved salts and was reduced by dilution. With zinc, on the other hand, the rate of solution increased as the concentration diminished, being greatest in distilled water. Carbon dioxide, moreover, played an important part in the solution of zinc. In the absence of CO_2 there was practically no solution of zinc in sea-water saturated with air, whilst the process was rapid in sea-water free from air but saturated with CO_2, and brass behaved similarly. The formation of the oxychlorides depended on the range of temperature and on the concentration of the salts.

It had been proved that local electromotive forces, due either to temperature differences or local variations in composition, played a large part, and an important point for settlement was the discovery of what protective electromotive force sufficed to afford security. He had tried the effect of coke, and found that Mr. Arnold Philips was right in the view that its presence might accelerate the solution of the zinc. In practice, however, the conditions in which it might act thus, could seldom arise, as the contact would be generally too poor, both with the metal of the tube and with the sea-water, owing, in the latter case, to the tendency of the pores to get filled with non-conductive deposits. The tests indicated that hard-drawn metal lost weight less rapidly than annealed, but it was more prone to localised attack.

The discussion was opened by Mr. Arnold Philip, who observed that the report was a somewhat monumental document, difficult to discuss, and he hoped that in a later publication it would be possible to marshal the facts in a more attractive form. He was glad to observe that his own views on the action of coke were now in part admitted. He thought that it would be of advantage if the rate of loss were more definitely expressed in the tables and curves, and suggested that the losses should be expressed as weights lost per sq. cm. per unit of time. He felt strongly that many repeat experiments must be made thoroughly to establish the results already recorded. He would admit that with the same conditions tests must lead to the same results, but the difficulty was so to control the work that the conditions really were unchanged. The report suggested that selective corrosion of copper occasionally occurred, and he would ask what was left in this case. When the zinc was dissolved selectively, the copper remained. Another point which arose was as to the character of ordinary sea-water. Dr. Bengough had asserted that at Liverpool the sea-water was always neutral, whereas the speaker had, with one exception, never found it other than alkaline to litmus paper. The one exception mentioned was water which had drained through a mangrove swamp. Dr. Bengough had said that he rendered his samples alkaline by adding bicarbonate of soda, which was, the speaker observed, a perfectly neutral salt, and could not, therefore, render sea-water alkaline. The speaker had, moreover, found most of his own samples alkaline to phenol-phthalein, which meant that a hydrate or monocarbonate was present, so that free CO_2 could not exist in such waters. In their references to aerated sea-water the authors did not make it clear whether the oxygen was dissolved throughout the mass or whether it existed as bubbles. All sea-water contained dissolved oxygen to a considerable amount, and if this were removed very different results would be recorded in corrosion experiments. He agreed that oxygen in the shape of bubbles did have a large effect at what the author called churning points, and it was well known that troubles arose from this cause near the entrance to condenser-tubes. The proposal to clean tubes *in situ* with weak acid was new to him, and he would like to see it tried, but on someone else's condenser. The suggestion was a novel one to him, and he would ask whether the authors had any experience of the method.

Mr. S. Smith, who followed, agreed with the previous speaker in the view that a greater boldness in the method of presenting the report would have been welcome, the authors being very non-committal in their conclusions throughout. Sections 1, 2, 3, and 5 of the paper should, be thought, be relegated to the shadows, whilst he would place sections 4, 6, 7, and 8 in the sun. He observed that a definition of what was to be regarded as corrosion was badly needed. He thought it should be confined to cases unexpected and unforeseen. The dezincification of brass had been treated with an air of mystery, but the phenomenon was wholly at one with the general behaviour of solid solutions. So far back as the eighth century Geber knew that silver could be selectively dissolved from a combination with gold. He could not help thinking that progress would be more rapid if the Committee could get away from the study of actual condenser-tubes, and study the corrosion of the zinc and copper alone. He noted a start in this direction had been made, and he thought this was vitally important. He might add that he had himself found that the rate of solution of silver was greatly modified by the size of the crystal grains. He had noted the same thing in copper, and the difference was accentuated by cold working. With zinc the effect was less marked.

Professor Carpenter, who spoke next, said that, as chairman of the Corrosion Committee, he should like to express to the authors his high appreciation of their work. It would have been noted that no reference had been made to the large-scale experiments; but, though the work was proceeding, it had not yet reached a stage in which a report could be usefully submitted, but perhaps a statement might be prepared for the autumn meeting. He noted that the copper-aluminium alloy used contained 7.92 per cent. of aluminium. It was thus very near the saturation point of the α solid solution, and, in fact, in the cast state would contain some β. On annealing this disappeared; but he should like to know if any were visible in the micro-structure of the tubes used. If the metal was not in thermal equilibrium, then a reduction of the aluminium would probably lead to improved results, as the rate of corrosion of two-phase systems was generally greater than that of single-phase ones. The tabulated results seemed to show this alloy to be superior to all three brasses, whilst the phosphor-bronze came last; yet Mr. Gibbs recommended that which, on the face of it, appeared decidedly the worst. The fact appeared to be that no one alloy was the best in all conditions; and in the absence of special protective measures, not one would be suitable for all waters and all temperatures. The copper-aluminium tubes came out exceedingly well, but containing only 8 per cent. of aluminium, the first cost would obviously be higher than that of brass tubes, and the important question was whether this difference would be great enough to prevent the use of the alloy as a substitute for brass.

Dr. W. Rosenhain also expressed regret that it had not been possible to present the report in a more digestible form. An attempt had been made to summarise some of the results, but in a very tentative way. He did not agree with Professor Carpenter that the copper-aluminium alloy would be improved by a diminution of the aluminium. The remedy for troubles arising from free air was to avoid negative pressures throughout the system. As to accelerated tests, he believed they had their uses, but there was a tendency to adopt them and swallow the resulting observations wholesale and without discrimination. With respect to experiments on the corrosion of zinc, it should be borne in mind that this metal had transformation points at relatively low temperatures, and its actual properties depended largely on its past history, so that on working with it a good deal of care was necessary to make sure of its real condition.

Sir Alfred Yarrow, called upon by the President, asked if the authors of the report had noted any effect due to the speed of the water flow. The experience of his firm had led them to believe that corrosion was much more rapid with low water speeds than with high, and they recommended engineers accordingly to keep up the speed of the circulating pumps, even when a boat was travelling at cruising speeds. The point was of importance, as the rate of corrosion of the tubes often determined the distance the boat could run before being laid up for repairs. He should like to know, therefore, whether he was right in believing that there was less corrosion with a rapid flow of water.

Mr. John Christy, who followed, noted with interest that the Committee thought the time had now come for them to supplement their inquiry into the causes of corrosion with an investigation of methods of prevention, which was the point of direct interest to users. There had been serious trouble with tube corrosion at the plant in his charge. Sea-water was used for circulating purposes, and the tubes gave out in twelve to eighteen months. The cost of replacement amounted to about 1000*l*., less the value of the scrap. He had tried to protect them by means of zinc, but with only partial success. The zinc was costly to replace and required constant attention, since it was ineffective unless kept clean. He had consulted many leading authorities and had recently adopted the process which was to be described that evening in Mr. Cumberland's paper. So far this had proved very satisfactory. In this method the electromotive force of the little electrolytic couples responsible for the corrosion was drowned out by a counter electromotive force supplied from an outside source. He had, as stated, found the method very satisfactory so far, and he hoped that the process would be thoroughly investigated by the Corrosion Committee. He agreed with Sir Alfred Yarrow that the corrosion was worse at low water speeds.

Mr. Rolfe, who followed, observed that it was a *sine qua non* that remedies for corrosion should not diminish the efficiency of the condenser, and certain of the recommendations made in the report must be regarded from this standpoint. The rate of flow which it was possible to adopt for a condenser was severely restricted. If not enough water was put through, the top tubes became ineffective; whilst if the quantity was too large, the cost of pumping became too high. There was thus some intermediate rate of supply which best suited the conditions. In power-station practice, with condensing water entering at 65 deg. Fahr. and leaving at 84 deg. Fahr., the quantity supplied was about 55 lb. of condensing water to

1 lb. of condensate. In all condensers, moreover, the velocity of flow must exceed a certain critical value. If below this, the water flowed through without turbulence, with the result that there was a cold core in the centre of the tube and a hot outside layer. In practice the velocity ranged from 4 ft. to 8 ft. per second. Applying these considerations to the recommendation to substitute parallel for series flow in condensers, this would mean that if the same quantity of water were sent through a four-flow condenser, the velocity would fall too low. The result would be a bad vacuum and a great loss of efficiency. If, on the other hand, it were intended to keep the velocity up to the normal value, four times the quantity of water would have to be pumped, which, as the static head would be 20 ft. or more, was a serious matter. The abolition of eddies might reduce corrosion, but it would at the same time seriously lower the efficiency of the condenser. The proposal to remove oxychloride deposits by means of acid (he presumed acetic acid would be used) had been dealt with by Mr. Philip, and would certainly require exceedingly careful control. As to the suggested cause of corrosion, to be satisfactory this must account for the concentration of the corrosion in the bottom of the water surface of the tubes; 90 to 95 per cent. of the failures occurred here, there being often very great pitting at the bottom, whilst the tops and sides of the tubes were not very much affected. This could not be explained by any theory which attributed corrosion to local differences in the physical condition of the tube. Whether it might be due to the action of oxychlorides was more debatable, if the oxychlorides fell to the bottom of the tube; but if they stuck all round the tube, their action would not account for the excessive corrosion at the bottom which was always observed. The speaker believed that the entrance of cathodic particles into the tube was the main responsible cause, and that protection would be best secured by providing a counter electromotive force from an outside source.

At the opening of the evening sitting, Mr. Rolfe exhibited a condenser tube which showed very severe pitting on the steam side. This tube proceeded from the condensers of a land power-station in which hundreds of tubes per year failed in the same way. The feed was peaty water, very soft, and the circulating water was sea-water. It was a remarkable fact that the pitting started and continued on the steam side and not on the water side. This was very interesting, since extreme corrosion took place generally on the water side. He (the speaker) thought there was more CO_2 in peaty water than in ordinary water, and Section V. of the report, which dealt with corrosion in solutions other than sea-water, pointed out that a large amount of CO_2 in the water formed a very virulent solution. Peaty water, therefore, containing free CO_2 should not be used as it was, but lime should be added to it, to get rid of the CO_2. The report, the speaker concluded, contained extremely valuable data which made the members much more sure of their ground. In reply to a query put by a member, Mr. Rolfe stated that the tubes, a pitted sample of which he exhibited, were of the Admiralty mixture 70+29+1.

The reply to the discussion was made at the evening meeting. Mr. W. E. Gibbs said he believed the proposal to include in the tables a time factor, made by Mr. Philip, would introduce difficulties, and it would probably be more advisable not to adopt it, but to state the period over which each test lasted, as had been done. In regard to the results of the previous reports, the figures had been calculated afresh, and in the present report the losses in weight had been put in milligrammes per square centimetre. He agreed with Mr. Philip that the statistical method was a good method to adopt. The speaker continued by stating that if in the tests the tarnish films were removed, better comparative results would be obtained. In their report, the authors had stated that when fresh sea-water was tested with phenolphthalein it showed no trace of alkalinity, whilst if it were allowed to stand one night, the surface water became faintly alkaline; the speaker added to this statement that the less salt there was dissolved in the water the greater was the proportion of free CO_2. This point, he thought, might bear upon the results obtained in sea-water. The report had described the aeration very fully. This was of two sorts, a gentle and a violent aeration. In the gentle aeration, the motion of the water relatively to the surface of the metal was as small as possible, whilst in the violent sort the air current flowed through a large orifice and impinged directly upon the metal. The violent aeration was more effective in the production of zinc oxychloride on the surface of the metal than the gentle sort.

He was very glad to hear Mr. Smith emphasise certain sections of the report, and he (the speaker) felt strongly that the best course to pursue was first to deal with pure metals, and then to deal with more complicated alloys; whilst in regard to corrosion he felt that it would be necessary to define it in the future more accurately than had been done in the past. He hoped Mr. Smith would put before the Institute the details of his own researches. In reply to Professor Carpenter, the Corrosion Committee had not examined other copper-aluminium alloys. The chief trouble met with was local pitting, and they had taken phosphor-bronze as best resisting this. But no one alloy had been found to satisfy all conditions; one given alloy resisted one effect, and another alloy resisted another. Dr. Rosenhain had referred to the bulk of the report; he (the speaker) would have liked to have been able to reduce it, but it was difficult sometimes to see a work in the true perspective when standing too near it, and that was in a sense the position in which the authors had been placed with reference to their work in question. There was a large future for experiments with copper-aluminium alloys containing deoxydising additions, such, for example, as vanadium. He (the speaker) had had an instance put before him of such an alloy containing 2 per cent. of vanadium which stood remarkably well. The local corrosion of propeller blades was most interesting, and it had, no doubt, been due to the presence of local air-pockets. In condenser-tubes on board ship the circulating water came in from the bottom, and under certain pressure conditions air was liberated to some extent, and there occurred a churning action, liberating air, apart from any effect due to the rise in temperature. The statement to the effect that it was necessary to bring the whole of the circulating water in contact with the hot condenser-tube was most interesting. The zinc used in the Corrosion Committee's experiments was pure Brunner-Mond zinc, cast and cleaned. Mr. Rolfe's interesting reference to corrosion occurring on the steam side of condenser-tubes was also most interesting; the occurrence was, however, not new. The researches the Committee had carried out had been essentially physico-chemical researches, and he believed that without sound physico-chemical work the problem of corrosion could not be solved.

The Chairman, in moving a vote of thanks to the authors, which was cordially responded to, added that he agreed with the remarks put forward in the course of the discussion by Sir A. F. Yarrow; he believed that full weight should also be given in the work to the engineering side of the problem.

The following papers were then taken in the course of the evening meeting:—"The Electrolytic Method of Preventing Corrosion," by Mr. Elliott Cumberland; "Notes on the Analysis of Aluminium and Its Alloys," by Mr. W. H. Withey, B.A.; and "The Annealing of Nickel Silver" (Part I.), by Mr. F. C. Thompson, M.Met., B.Sc. The first two alone were discussed; we shall deal further with these in our next issue.

THE LATE MR. JOHN STEPHEN, OF LINTHOUSE.

By the death of Mr. John Stephen, at his residence "Domira," Partickhill, Glasgow, on the 27th inst., there has passed away, to the regret of many friends, an engineer who contributed much to the renown of the Clyde for shipbuilding and engineering. Mr. Stephen, who was within a few weeks of his eighty-first birthday, was, for the whole of his life, identified with the firm of which he ultimately became the head—Messrs. Alexander Stephen and Sons, Limited. Along with his brother, Mr. Alexander Stephen, he built up an establishment which occupies a prominent place among the many notable shipyards on the river. By their fair-mindedness and continuous sympathy with all classes the two brothers developed a close, friendly relationship with the workers in all branches of the establishment. They displayed all those qualities of industrial leaders which find expression in the promotion of the welfare of the community in which their works are located; and Linthouse, which was for long an isolated community 3 or 4 miles west of Glasgow, on the south side of the river, owed much in its ecclesiastical and philanthropic life to the Stephens.

The subject of this memoir was the grandson of Mr. William Stephen, who, in the middle of the eighteenth century, was a builder of sailing vessels in Aberdeen, and the son of Mr. Alexander Stephen, who began shipbuilding first at Arbroath, where the late Mr. John Stephen was born, in April, 1835. Later his father moved to Dundee, where he continued the building of sailing-ships and the construction of steam whalers, and the family subsequently established also a shipbuilding yard at Kelvinhaugh, Glasgow. The late Mr. John Stephen was educated at Brechin Grammar School and Edinburgh University, and served his apprenticeship as an engineer at Messrs. Randolph and Elders, proceeding thence to the Dundee Yard, where he gained experience in shipbuilding. He added to his experience by making a voyage to the Mediterranean in the s.s. Euphrates as third engineer. Three years later, in 1859, he joined his brothers Alexander and James in the Kelvinhaugh Yard. The prosperity of the firm rendered extension necessary, and in 1868 there was purchased the estate of Linthouse, covering an area of 52 acres, and there, two years later, the works were in full operation.

One result of the advent to the firm of the subject of this memoir was the addition of an engineering branch to the concern, and here his engineering experience enabled the firm at once to achieve success in the equipping of steamers with their machinery. The firm continued to progress, and a review of the work they have done would show that they occupied a prominent place, not only for the extent of their operations, but for their contributions towards the development of shipbuilding and marine engineering. They were the first on the Clyde to build an Atlantic liner fitted with the steam-turbine, and it was in one of their turbine boats that the practice of putting multiple propellers on the same shaft was first proved to be disadvantageous. Mr. John Stephen took a keen practical interest in all the work done, in co-operation with his brother, Mr. Alexander Stephen, until his death in 1899, and with the latter's sons, Mr. A. E. Stephen and Mr. F. J. Stephen. Up to the time of his death he continued to be the head, as chairman, of the limited liability company formed for family reasons. Although for the last two or three years his health had not been very good, he made occasional visits to the works.

The late Mr. Stephen took a keen interest in the affairs of the Burgh of Govan, of which Linthouse formed a part, and he was closely identified with the Free, and later, the United Free Church, supporting it in many ways. He was also closely identified with foreign mission work, founding the Livingstonia Mission in Africa. A visit to Africa resulted in the carrying out of schemes for the extension of the trade on the Zambesi River. He was predeceased by his wife, and leaves no family.

RAILWAY WAGONS.

FIVE railway companies—the London and North-Western, Great Western, Midland, North-Eastern, and Lancashire and Yorkshire—are, as an experiment, pooling open deep-sided wagons of three or more planks. The arrangements are set forth in the following circular:—

Commencing at 4 p.m. on Sunday, April 2, 1916, and until further notice, all open deep-sided wagons of three or more planks, with doors on each side, belonging to the Great Western, London and North-Western, Midland, and North-Eastern Companies, and those of the Lancashire and Yorkshire Company specially marked with four white crosses on each side, will be available for use as common stock for the purpose of the five companies, with the following exceptions:—

All coke wagons.

All wagons which have not side-doors the full depth of the wagon.

All wagons exceeding 21 ft. in length over buffers and 10 ft. 6 in. in wheel-base.

Great Western vacuum-fitted stock.

Great Western high-sided wagons used for military horses.

Midland hopper-bottom, end-door, and 12-ton high-sided wagons.

North-Eastern open fish, salt, and sleeper wagons.

All other vehicles, including the exceptions, must continue to be dealt with in accordance with existing regulations.

On dock estates, harbours, collieries, and works served by either one or more of the five companies parties to the common user arrangement, the user of the five companies' wagons in common is permissible to or *via* the lines of any of the five companies concerned, but not otherwise.

All companies outside these arrangements must return the wagons of the five companies named directly and promptly to the owning companies.

J. A. F. ASPINALL.
A. KAYE BUTTERWORTH.
GUY CALTHROP.
GUY GRANET.
F. POTTER.

NEW ROUTE TO SWEDEN.—There is to be laid, during the present session, before the Swedish Riksdag a project for a daily service between Gothenburg and some English port, probably Immingham. The service is to be ensured by large State steam vessels, of some 10,500 tons, built and worked by the State, as are the Swedish international steam ferries.

INDUSTRIAL NOTES.

DESPITE the fact that the shipping problem has been discussed by the Boiler-Makers' and Iron and Steel Shipbuilders' Society, and that they have addressed a letter to the Prime Minister and the Chancellor of the Exchequer advising them how to proceed in the disposing of the 500,000 tons of mercantile shipping now being completed by the consent of the Government, and also that the Boiler-Makers make the statement "that the Government have decided upon financial assistance to shipbuilders to finish such contracts," we are reminded that no financial arrangement has been arrived at as between the President of the Board of Trade and the Shipbuilders Employers' Federation. As a matter of fact, the President of the Board of Trade made it abundantly clear in an interview on February 24, with a deputation from the Federation referred to, that the Government had not any intention of rendering such assistance. The only facilities granted to shipbuilders have been in regard to the completion of the half million tons of mercantile shipping, and the "concessions" amount to using labour on mercantile work and ranking it as war work. No compensation has been granted to shipbuilders on account of their breaking contracts at the outbreak of war and proceeding to the building of ships on Admiralty account.

The Minister of Munitions announces that he has made further Orders under the Munitions of War Acts, 1915 and 1916, under which 259 additional establishments have been declared controlled establishments under the Acts. A total of 3337 establishments has now been declared as controlled under the Acts from the date of the first Order, July 12, 1915, up to March 27, 1916.

Negotiations are proceeding between the Ministry of Munitions and the Amalgamated Society of Engineers regarding the appointment of local joint committees representative of employers and unions directly interested in the working of the Munitions Act. Local labour advisory boards already exist in the different industrial districts of the country, but it is understood that the local committees, promised to the engineers some months ago, are likely to be established without much further delay. The object in forming these committees is to assist in harmonising and smoothing the working of the Act, and in dealing with questions likely to cause friction in workshops and munition areas before they become acute.

In the course of Wednesday's proceedings in Parliament Dr. Addison, in the absence of the Minister of Munitions, and in reply to a question, dealt with the industrial situation on the Clyde. He stated that in the course of the past week several strikes had been organised in some of the most important munitions works in the Clyde district by a self-appointed body known as the Clyde Workers' Committee. This was originally styled, Dr. Addison believed, the Clyde Labour Withdrawal Committee; it repudiated any connection with or allegiance to established trade unions, and decided, about a fortnight ago, to embark on a policy of holding up the most important munitions of war in the Clyde district, with the object of compelling the Government to repeal the Military Service Act and the Munitions of War Acts, and to withdraw all limitations upon increases of wages and strikes in all firms under Government control. One of the chief members of this Committee insisted that he should be entitled during working hours to leave his work in his own department for investigating what was being done with unskilled labour. The management referred the matter to the Clyde Commissioners, who had secured the confidence both of the local trade-union leaders and of the employers. The man in question and his associates declined, in breach of their own agreement, to place the matter before the Commissioners and succeeded in bringing out about a thousand men in one works. From that time a series of strikes appear to have proceeded upon a systematic and sinister plan.

The executive of the Amalgamated Society of Engineers, on the matter being reported to them by their local officers, immediately issued a statement repudiating the strike, and calling upon the men to return to work. These efforts were unfortunately unsuccessful, and the Minister of Munitions requested the military authorities to remove, under Section 14 of the Defence of the Realm Regulations, six of the ringleaders, who were found, with others, to be contemplating a further extension of their operations. The movement, added Dr. Addison, had no connection whatever with any industrial grievance. It was repudiated by the official trade unions, and was plainly deliberately organised and directed to hold up certain munitions of war of which the Army in the field had the most urgent need. The Ministry were satisfied that in their action they had the support of the vast majority of the munition workers on the Clyde, who were opposed to this illegal action of the Clyde Workers' Committee, and they had the support also of the trade unions, against whose existence and authority the operations of this organisation were directed as much as against the Government. The Ministry of Munitions had received loyal assistance and co-operation from the executive of the Amalgamated Society of Engineers and from their local organisers.

Twenty-two munition-workers who took part in the strike referred to by Dr. Addison were brought before the General Munitions Tribunal in Glasgow on Wednesday. An adjournment was asked for on behalf of the men, because of the internment of the leaders. The men also refused to resume work unless the leaders were released. No hope was held out of such release, and the case proceeded. It was made abundantly clear that there was grave interference with work of extreme importance to the nation, and the men were fined each 5*l.*, to be deducted from their wages at the rate of 1*l.* per week. It seems doubtful if this ends the grave situation in the Clyde district.

We read in the *Manchester Guardian* that an application for a 10 per cent. advance of wages is to be made by the Amalgamated Association of Operative Cotton-Spinners to the Federation of Master Cotton-Spinners' Associations. This was decided upon at the annual meeting of the operative spinners on Saturday afternoon. The meeting was private.

In communicating the decision, Mr. W. Marsland, the secretary, explained that the application was founded upon the profitable margins between cotton and yarn. Something on the same subject appears in the report of the executive committee of the Association for the quarter ended January 31 last.

"Three months ago (the committee say) we expressed the opinion that the cotton-spinning mills would have a profitable run of trade for some time to come. This has been fully borne out by the business done during the past quarter. The margins between cotton and yarn, judged by the standards which we have always taken and which have proved very safe guides to us of the state of trade, have been higher than for a long time past. With good middling American cotton and 32's twist and 40's weft as a basis there is a margin of over 4¼d. per pound, while between good Egyptian cotton and 60's twist the margin is nearly 8d. These are certainly phenomenal, particularly during war-time, and show the wonderful recuperative powers of our great industry, which was completely at a standstill about eighteen months ago. After taking into consideration the great increase in the cost of materials, freights and stores, together with the loss of production due to machinery being stopped owing to shortage of workpeople, there is ample margin for the capitalist side of the business."

The meeting, which was presided over by Mr. Edward Judson, of Ashton-under-Lyne, also decided to grant 5000*l.* to the British Red Cross Society and the St. John Ambulance Association, either for the provision of motor ambulances or towards the cost of a hospital ship, whichever those organisations prefer.

Sir George Askwith, the Chief Industrial Commissioner, received in London, on Thursday, the 23rd inst., a deputation from the National Union of Dock Workers (Liverpool), and listened to their claim for an advance of 2d. per hour to Liverpool and Birkenhead dockers working on night-shifts. The union stated that the night workers have had no increase in wages since the beginning of the war, and that an advance of 2d. an hour is justified when the day rate is compared with the present night rate. The minimum day rate is 6s., while the night pay is 8s., which is less than time-and-a-half, and the men contend that they ought to have time-and-three-quarters.

Decision was reserved.

Following upon our paragraph on page 287 *ante*, with reference to the points in dispute with the South Wales miners, we are informed that Mr. Runciman, President of the Board of Trade, decided last week to appoint a conciliator for considering the points put forward by the men. The latter, we understand, have agreed to take no further action in the meantime. Moreover, the gale has had the effect of delaying the men's conferences at Cardiff on the controversy.

An enterprising person has opened, in one of the Scandinavian countries, we are told, a bureau for the export of labour from Scandinavia to Germany. The different unions of German employers have been circularised by the said bureau, which charges 20 kr. (22s. 6d.) per hand whose services have been engaged; the employers have to pay the passage to the German works, the passport charges, &c., whilst the workmen have to undertake to serve for at least two months. Nothing much is likely to result from this propaganda, which seems equally unpopular both in Scandinavia and in Germany. Moreover, in Norway the law prohibits such foreign trading in labour. That some men, on their own account, may try their luck in pursuance of the scheme is another matter; so far, however, there seems to be very little inclination that way, and no wonder.

The annual report of the Interstate Commerce Commission, referring to the operation of the Sixteen-Hour Law, discloses the fact, says the *Railway Review*, Chicago, that long hours in train service have been reduced to a minimum. Only one employee in five on the average last year was compelled to remain on duty more than sixteen hours during any one day of the whole year. The number of cases of excess service from all causes reported to the Commission was 61,247 during the year ended June 30, 1915, compared with 137,439 in 1914 and 270,827 in 1913.

According to the same American journal, representatives of the railway employees' organisations, who have been in conference in Chicago, canvassing the referendum vote of the unions relative to their wage demands, had expected to be able now to announce the result of the vote. The following statement given out at the close of the session held on the 9th inst. describes the situation on that date:—"While the returns are not fully completed, it is evident that the vote is overwhelmingly in favour of presenting to the railway companies of the United States the request for the eight-hour day and time plus one-half for overtime. Consequently, the movement with that object in view will be carried forward in its regular course. The present vote has no significance whatever as an indication of the desire of the men that this matter should be pressed to a conclusion, and all reports that it has any significance as a strike vote are erroneous and misleading. The request will be presented to the railway managements and the necessary steps taken to make the same effective."

NOTES FROM THE UNITED STATES.

PHILADELPHIA, March 15.

A GOODLY number of consumers of steel are facing a new obstacle; they are unable to place orders for steel at a price they can afford to pay. The trouble has arisen out of the rapid advance of steel during the past few months. Domestic requirements for steel for delivery from six to nine months ahead are expanding more rapidly than others. The possibility of a break in prices from the present abnormal advances has to be taken into account. There are no prospects for a break as far ahead as business interests can see. Capacities continue to expand. At present 312 blast-furnaces are producing 107,510 tons a day, which means 39,241,150 tons per year. Heavy buying of munitions continues. Eighty thousand tons of pig-iron exchanged hands in the Pittsburg district within the past week. The output and shipment of steel for February was the largest in the history of the trade. The average price of the steel products is now 49 dols. a ton, as compared with 20 dols. a year ago. This high price naturally checks a great deal of enterprise. That prices will decline to the level of a year ago is extremely improbable, because of the enormous foreign wastage to be replaced, as well as the meeting of the newer demand which the war has created.

The magnitude of domestic requirements cannot be even guessed at, because of the inevitable increase of manufacturing capacity, to say nothing of the demand abroad which the post-war developments will precipitate on American capacity. It looks as though this Government would have a Mexican war on its hands very soon. Plates lead in activity over all other mill products; material for munition manufacture comes next. Railroads continue to order liberal rail supplies. American business sense refuses to accept the probability that present abnormal prices will continue, and accepts the theory that European munition facilities will be equal to the task of meeting all post-war demands. Railroad expansion is becoming more and more imperative.

THE MANCHESTER ASSOCIATION OF ENGINEERS.—The annual meeting of the above Association was held on Saturday last, when Mr. F. Reed, of Craven Brothers (Manchester), Limited, was elected president for the year, Mr. Sam Boswell retiring pursuant to rule. Subsequently Mr. Dempster Smith submitted an interim report of the Tool-Steel Research Committee of the experiments made at the School of Technology, Manchester, up to May 21, 1915, a synopsis of which is as follows:—This report is a supplement to the report of Past Experimental Work on Cutting-Tools, presented to the Association a year ago. The committee drew up a suitable programme of tests, but, owing to the prevailing stress, only one portion of this programme could be adequately dealt with. The report discusses the question of heat treatment on tool-steel, and the attempts of the committee to ascertain whether uniformity of results could be obtained in any successive trials made under identical conditions. Tests have been made to ascertain whether a tool that has failed in use is less serviceable after being simply re-ground, and if so, whether heat treatment restores the tool to its original vitality. The opinion of several experts is given on the question of heat treatment and the possibility of obtaining uniform results. The report deals with some effect due to carrying the heat treatment to different stages, normalising and tempering.

THE CORROSION OF METALS.

*Third Report of the Corrosion Committee of the Institute of Metals.**

By WILLIAM E. GIBBS, M.Sc. (Special Lecturer in Metallurgy in the University of Liverpool), RICHARD H. SMITH (late Wiggin Scholar in Metallurgy in the University of Birmingham), and GUY D. BENGOUGH, M.A., D.Sc. (Lecturer in Metallurgy in the University of Liverpool).

SECTION VII.

GENERAL SUMMARY.

In considering the results of this investigation we have to remember that laboratory experiments are necessarily carried out under artificial conditions. It is almost impossible to reproduce in the laboratory the steady flow of a constantly fresh supply of sea-water that is obtained in a condenser-tube in practice. When a piece of brass is corroding in a limited supply of sea-water, it produces a rapid change in the character of the sea-water itself. The formation and precipitation of copper oxychloride reduces the concentration of chlorine in the sea-water and increases the alkalinity. At the same time a considerable amount of zinc dissolves in the sea-water.

Now it is found that the formation of zinc oxychloride upon the surface of the metal occurs far more rapidly in a small volume of sea-water than in a large volume. It appears that the concentration of Cl or NaCl in sea-water is relatively too high for the formation of this salt at temperatures below 50 deg. Cent. In any case a reduction in the concentration of Cl, either by the dilution of the sea-water or by the gradual precipitation of copper oxychloride, accelerates the formation of the zinc oxysalt. It is clear, therefore, that in these laboratory experiments the sea-water tends more and more to promote dezincification as corrosion proceeds. This effect can be minimised by using relatively large volumes of sea-water and changing it frequently. This has been done in most of the experiments described in this report.

In some experiments, notably those with diluted sea-water, small particles of zinc oxychloride are formed. These float about in the sea-water, and are continually coming into contact with the surface of the metal. The conditions are therefore made more favourable for the formation of deposits of this salt upon the metal. It is possible that this factor might be eliminated by circulating the water through a suitable filter. An apparatus has been devised and constructed for this purpose and will be used at the earliest opportunity. It is hoped by this means also to decide whether the zinc oxychloride is deposited upon the metal from the solution or formed directly at the surface of the metal. It is quite certain, however, that after due allowance has been made for these limitations, the results of these laboratory experiments are very important and throw considerable light upon the character and magnitude of many factors in the somewhat complicated processes of erosion. It will be well to consider these factors separately, firstly in their relation to the corrosion of 70 : 30 brass, and subsequently to that of each of the other alloys. In this way we shall be able to see clearly the extent to which each factor in the process is affected by the composition of the alloy.

The Brasses. Temperature.—The corrosion of the three brasses in stagnant sea-water has now been investigated at 15 deg., 30 deg., 40 deg., 50 deg., and 60 deg. Cent. Generally speaking, it is found that the alloys begin to dissolve more rapidly as the temperature is raised. At the same time the rate of corrosion falls off more rapidly, and general corrosion of the alloy ceases in a shorter time at the higher temperatures. 70 : 30 brass behaves in an exceptional manner at 60 deg. Cent., its rate of solution being smaller at that temperature than at 30 deg. Cent.

Loss of Weight in Milligrammes per Square Centimetre.

70 : 30 *Brass.*

Week.	15 deg. C.	30 deg. C.	40 deg. C.	50 deg. C.	60 deg. C.
1st ..	0.32	0.45	0.52	0.65	} 0.55
2nd ..	0.28	0.25	0.20	0.30	
3rd ..	0.20	0.20	0.08	0.17	} 0.25
4th ..	0.16	0.16	0.04	0.12	
5th ..	0.14	0.12	0.12	0.09	—

70 : 29 : 1 *Tin-Brass.*

1st ..	0.42	0.42	0.48	0.45	} 1.47
2nd ..	0.36	0.36	0.06	0.25	
3rd ..	0.30	0.34	0.08	0.10	} 0.65
4th ..	0.24	0.33	0.10	0.01	
5th ..	0.18	0.30	0.12	0.00	—

70 : 28 : 2 *Lead-Brass.*

1st ..	0.32	0.37	0.44	0.55	} 0.75
2nd ..	0.20	0.30	0.20	0.15	
3rd ..	0.16	0.28	0.16	0.11	} 0.19
4th ..	0.15	0.20	0.12	0.08	
5th ..	0.12	0.15	0.20	0.09	—

The general effect of temperature upon the rate of corrosion of the hard-drawn alloys is shown in the tables above, in which the loss of weight per week for five successive weeks is shown for each alloy at five temperatures. The figures for 30 deg., 50 deg. and 60 deg. Cent. are interpolated from the curves given in this report, and for 15 deg. and 40 deg. Cent. are calculated from the Second Report. It will be noticed that the addition of 1 per cent. tin to the 70 : 30 brass accelerates the rate of solution at 15 deg. and 60 deg. Cent. At the intermediate temperatures it diminishes it. The addition of 2 per cent. of lead diminishes the rate of corrosion at temperatures below 50 deg. Cent., but increases it at 60 deg. Cent.

A rise of temperature also produces a change in the character of the attack. At temperatures below 50 deg. Cent., 70 : 30 brass becomes dezincified after a lapse of time which becomes shorter as the temperature rises. White spots of zinc oxychloride are formed upon the surface of the metal, and are found to cover areas of spongy copper. At 50 deg. Cent. localised dizincification also occurs, but the residual copper dissolves rapidly, and a pit is formed. If zinc oxychloride is formed upon the metal—*e.g.*, by prolonged contact with a bubble of air—dezincification will proceed rapidly, and the residual copper will be protected by the deposit of oxychloride, and will not dissolve.

The 70 : 29 : 1 tin-brass is more resistant to dezincification than the 70 : 30 brass at 40 deg. and 50 deg. Cent. It is less resistant at 30 deg. and 60 deg. Cent.

The 70 : 28 : 2 lead-brass is more resistant to dezincification at all temperatures.

Aeration of the Sea-Water.—There are two kinds of aeration, "gentle" and "violent." With "gentle" aeration the mechanical agitation of the water is reduced to a minimum. In "violent" aeration it is a very important factor. Gentle aeration of the sea-water increases the rate of corrosion at 70 : 30 brass at 15 deg. Cent., exerts very little effect upon it at 50 deg. Cent., and diminishes it at 60 deg. Cent. In every case it increases the rate of dezincification. In this connection it is interesting to notice that aeration alters very slightly the rate of solution of pure copper, but increases very considerably that of pure zinc.

"Violent" aeration promotes the formation of zinc oxychloride. This salt is formed readily whenever brass is in contact simultaneously with air and sea-water at temperatures above 40 deg. Cent. Such conditions might occur along the water-line in a partially-filled condenser tube. Aeration increases the rate of corrosion of 70 : 29 : 1 at 50 deg. Cent. and diminishes it at 60 deg. In diluted sea-water at 50 deg. Cent. aeration rapidly promotes dezincification.

Aeration diminishes very considerably the rate of corrosion of the 70 : 28 : 2 lead-brass at 50 deg. and 60 deg. Cent. It does not appear to promote dezincification In diluted sea-water at 50 deg. Cent. it promotes severe localised dezincification.

Composition of the Sea-Water.—In all the experiments with diluted sea-water the solution was gently aerated. The temperature was 50 deg. Cent. The rate of corrosion is lessened by the dilution of the sea-water. At the same time the proportion of zinc in the corrosion product is greater in diluted sea-water than in ordinary sea-water.

This is in accordance with the corresponding observation that the rate of solution of pure copper is diminished by diluting the sea-water, and is least in distilled water, while, on the other hand, that of zinc is very considerably increased by diluting the sea-water and is greatest in distilled water. It would seem, therefore, that gently aerated distilled water should be actively dezincifying. This suggests that dezincification is produced by the dissolved gases in the sea-water rather than by the dissolved salts. It is found that brass is rapidly dezincified by distilled water containing CO_2. It is also dezincified by sea-water containing CO_2 but free from oxygen. Pure zinc is very little acted upon by sea-water which is aerated by air that is free from CO_2. It is suggested, therefore, that CO_2 is an essential factor in the dezincification of brass by sea or river water.

White spots of zinc oxychloride and carbonate are formed more readily in diluted sea-water. They appear to be formed only within a limited range of concentration of the sea-water solution, at a given temperature. At 50 deg. Cent. they are formed upon 70 : 30 brass in S/2, S/4 and S/8 sea-water—*i.e.*, sea-water which is respectively $\frac{1}{2}$, $\frac{1}{4}$ and $\frac{1}{8}$ of the concentration of ordinary sea-water (S/1). On 70 : 29 : 1 brass they are formed most readily in S/8 and S/16 sea-water—*i.e.*, in more dilute solutions.

The 70 : 28 : 2 brass behaves differently from the other brasses. Large pits filled with white salt are formed upon the metal in S/2, S/4, S/8 and S/16 sea-water. These pits are few in number and widely separated from one another. They grow rapidly.

The addition of 2 per cent. of lead to the 70 : 30 brass therefore diminishes greatly its resistance to the localised selective attack of diluted sea-water. The addition of 1 per cent. of tin increases its resistance, except in very dilute solutions. In these it greatly diminishes it. These alloys are dezincified by a 0.15 per cent. NaCl solution at 30 deg. and 50 deg. Cent., and also by distilled water containing CO_2 at 15 deg., 30 deg. and 50 deg. Cent. They are actively dezincified by a 0.15 per cent. NaCl solution through which CO_2 is passed continuously. In no case, however, was any white salt formed upon the metal in these solutions. Clearly, therefore, a low salt content, combined with a relatively high concentration of CO_2, such as might occur in some estuary and river waters, promotes active dezincification of these zinc-copper alloys.

The Physical Condition of the Metal.—In nearly every case the rate of corrosion of the hard-drawn 70 : 30 alloy is smaller than that of the annealed alloy. At the same time the hard-drawn alloy is attacked locally and selectively to a much greater extent than the annealed alloy.

It is suggested that small electromotive forces are set up on the surface of the metal between strained and unstrained metal, whereby the strained metal is dezincified and dissolved the more rapidly. Wherever the metal is strained by filing or drilling it is found to be dezincified uniformly and covered with a layer of cuprous oxide.

Hard-drawn 70 : 29 : 1 loses weight more rapidly than the annealed in all the solutions examined with one exception, sea-water at 50 deg. Cent. In nearly every case the difference between the hard-drawn and annealed metal is very small. It appears, therefore, that the addition of 1 per cent. of tin to the 70 : 30 brass minimises the difference between the hard-drawn and the annealed alloy.

Hard-drawn 70 : 28 : 2 loses weight less rapidly than the annealed except in 0.15 per cent. NaCl and sea-water at 50 deg. Cent. Dezincification and localised corrosion were more pronounced upon the hard-drawn alloy.

The Surface Condition of the Metal.—Selective corrosion generally begins at the strained metal, *e.g.*, draw-lines, drilled holes, filed edges. A polished surface corrodes very slowly and quite uniformly. Surface irregularities constitute *loci* for the formation of air-bubbles. At high temperatures the air-bubbles may promote the formation of zinc oxychloride and so give rise to dezincification. Sea-water evaporating on 70 : 30 brass at 100 deg. Cent. produces zinc oxychloride.

Contact with Foreign Substances.—Porous substances, such as string, in contact with 70 : 30 brass, may promote a rapid localised attack. It is probably due to oxysalts absorbed by the string, and also to the absence of the free circulation of the sea-water and diffusion of the dissolved air. The action is increased by raising the temperature. With 70 : 29 : 1 the action of the string is more marked, with 70 : 28 : 2 it is much less marked.

Contact with ordinary soft glass is found to promote dezincification at 50 deg. Cent. A red, loosely adherent film of cuprous oxide is produced. Contact with cathodic substances, such as coke, has been found to promote dezincification of the 70 : 30 : 1 alloy. The action is accelerated by raising the temperature. A hydrocarbon oil—liquid vaseline—readily dissolves copper from 70 : 30 brass in aerated sea-water at 50 deg. Cent. to form a green copper solution.

The Phosphor-Bronze.—This alloy corrodes much more rapidly than the brasses, in fact, more rapidly than pure copper. The rate of corrosion is increased by raising the temperature. It falls off slowly with time at 30 deg. Cent. and 50 deg. Cent., but rapidly at 60 deg. Cent. This corresponds to the occurrence of a severely selective attack at 60 deg. Cent. The loss of weight, in milligrammes per square centimetre, during the first five consecutive weeks, at 30 deg. Cent., 50 deg. Cent., and 60 deg. Cent., is shown in the following table:—

Week.	30 Deg. Cent.	50 Deg. Cent.	60 Deg. Cent.
1st	0.50	1.00	} 2.17
2nd	0.45	0.95	
3rd	0.45	1.30	} 0.55
4th	0.45	1.85	
5th	0.42	1.85	—

Localised loss of tin occurs at 30 deg. Cent. and 50 deg. Cent., but no tin oxysalt is formed. At 60 deg. Cent., however, a white tin oxysalt is formed, and promotes rapidly the selective corrosion of tin.

Aeration.—Aeration increases the rate of corrosion at 50 deg. Cent., and diminishes it very considerably at 60 deg. Cent. It tends to repress selective corrosion of the tin.

Composition of the Sea-Water.—Phosphor-bronze dissolves less rapidly in diluted sea-water at 50 deg. Cent. than in ordinary sea-water. Selective corrosion of the tin increases with dilution until S/4 sea-water is reached, and then diminishes rapidly as the dilution of the sea-water is further increased. No oxysalt is formed in these solutions at 50 deg. Cent. Distilled water containing CO_2 dissolves tin from phosphor-bronze at 30 deg. Cent. and 50 deg. Cent. No oxysalt is formed. 0.15 per cent. NaCl solution exerts no selective action at 30 deg. Cent., but at 50 deg. Cent. produces a very marked loss of tin.

Physical Condition of the Metal.—In every case, except in sea-water at 30 deg. Cent., the hard-drawn metal loses weight more rapidly than the annealed. Selective corrosion occurs irregularly, sometimes upon the hard-drawn metal only, sometimes the annealed, frequently both. The phosphor-bronze differs from the zinc-copper alloys in two things—(*a*) its rate of solution is very much greater; (*b*) the tin oxysalt is formed at much higher temperatures than the corresponding zinc salt.

The Aluminium-Copper Alloy.—The rate of corrosion of this alloy is very much smaller than that of brass. It is increased considerably by raising the temperature. It falls off with time more rapidly at 30 deg. Cent. than at the higher temperatures. The loss of weight of the hard-drawn metal during each of the first five consecutive weeks is shown in the following table:—

Week.	30 deg. Cent.	50 deg. Cent.	60 deg. Cent.
1st	0.10	0.20	} 0.47
2nd	0.07	0.20	
3rd	0.05	0.16	} 0.23
4th	0.04	0.14	
5th	0.03	0.12	—

This alloy is selectively corroded more readily than brass at 30 deg. Cent., and less readily at 50 deg. Cent. and 60 deg. Cent.

Aeration of the Sea-Water—Gentle aeration of the sea-water diminishes the rate of corrosion at 50 deg. Cent. and 60 deg. Cent. It does not appear to promote selective corrosion at either temperature.

Composition of the Sea-Water.—This alloy appears to dissolve more rapidly in diluted sea-water than in ordinary sea-water. The proportion of aluminium in the corrosion product is practically constant in S/2, S/4, and S/8 sea-water. It is much smaller in S/1 and S/16 sea-water. Large deep pits are formed upon the metal in diluted sea-water of all the degrees of dilution considered

* General Summary forming conclusion of paper read before the Institute of Metals on March 29. The report itself extends to so great a length that it is not possible to publish it *in extenso*.

in these experiments. These pits were filled with a white salt, and in appearance and distribution were very similar to those formed upon the 70 : 28 : 2 brass. This alloy was singularly resistant to distilled water containing CO_2, both at 30 deg. and 50 deg. Cent. It behaved in a similar manner in 0.15 per cent. NaCl solution at 30 deg. Cent. In each case the metal assumed a uniformly pale yellow matte surface, and appeared to be covered with a very thin film of white salt. In 0.15 per cent. NaCl at 50 deg. Cent. this alloy was severely attacked selectively—to a much greater extent than any of the other alloys.

The Physical Condition of the Metal.—In nearly every case the hard-drawn metal loses less weight than the annealed. In two instances they behave with remarkable similarity. In one instance—viz., CO_2 and distilled water at 30 deg. Cent., the hard-drawn metal dissolves more rapidly than the annealed. Generally speaking this alloy is by far the most resistant of any considered in this report. It is, nevertheless, very severely attacked in diluted sea-water at 50 deg. Cent. and in 0.15 per cent. NaCl at 50 deg. Cent., and in ordinary sea-water at 30 deg. Cent. Compared with the zinc-copper alloys—(*a*) its rate of corrosion is very small; (*b*) it is not attacked to any great extent by dissolved CO_2. But it is much more severely corroded in ordinary sea-water at 30 deg. Cent. and in diluted sea-water at 50 deg. Cent.

SECTION VIII.

SOME OBSERVATIONS UPON THE BEARING OF THE RESULTS OF THE EXPERIMENTAL WORK UPON PRACTICAL CONDITIONS.

Before considering the bearing of this work it will be well to state briefly the main features of the practical conditions. A brass condenser-tube in service may corrode uniformly and "completely," in which case the tube will probably last a very long time, and is not likely to cause any trouble. Generally, however, corrosion occurs in definite spots and areas which are distributed irregularly along the tube. In the great majority of cases it is found that this localised attack is concentrated upon the zinc, and produces spots and areas of spongy copper. This residual copper either remains undissolved, and ultimately forms a copper plug extending through the wall of the tube, or it is dissolved or worn away mechanically, and a pit is formed which, in time, leads to perforation of the tube. The outstanding features of the practical problem to be dealt with, therefore, are how to prevent:—

(A) "Selective" removal of zinc from the brass, either uniformly or locally.

(B) Localised attack—*i.e.*, in spots and areas.

(A) *The Occurrence of Uniform Dezincification.*—It has been shown in this report that a brass tube is dezincified most readily—

(*a*) If the sea-water be aerated—particularly if the aeration be violent.

(*b*) If the amount of carbon dioxide dissolved in the sea-water be increased.

(*c*) If the concentration of dissolved salts be diminished.

(*d*) If the temperature of the sea-water be raised unduly, as, for example, in a choked tube.

(*a*) Practically all the water as it flows through the tubes of a condenser is in a state of aeration. Just inside the inlet end of each tube the water shows a tendency to froth and churn, owing to the obstruction which is offered to the smooth flow of the incoming water by the projecting ends of the ferrules. This churning takes place at a definite point—the churning point—after which the water settles down to a smooth flow along the tube. The distance of the churning-point from the inlet end depends upon the speed of the water and the dimensions of the tube, and under ordinary conditions will be fairly constant. At the churning-point the water is in a state of violent agitation, and any particles of solid matter that may be in suspension in the water will be dashed against the wall of the tube, and so produce continual erosion of the tube in that locality. At the same time it is found that such violent aeration of the water increases greatly the rate of "complete" corrosion, particularly at low temperatures. It is suggested that the rapid localised corrosion which occurs so frequently just inside the inlet end of condenser-tubes is due to this local churning and aeration of the water, and any copper resulting from dezincification may also be worn away mechanically by erosion.

(*b*) The water of many rivers, particularly in the tropics, contains a considerable proportion of carbon dioxide, which, under certain conditions, is formed from decaying vegetation.

(*c*) The concentration of dissolved salts is much smaller in estuary waters than in the water of the open sea, and, of course, the concentration of salts in river-water is very much smaller still. The solubility of carbon dioxide and oxygen has been shown to be greater in diluted sea-water than in ordinary sea water.

It seems probable, therefore, that estuary waters will be more selectively corrosive than ordinary sea-water, because they contain less salt and more oxygen and carbon dioxide.

(*d*) The action of estuary water will be enhanced in many tropical harbours by the higher temperature attained in the condensers.

The natural result of such uniform dezincification would be the production of a film of copper all over the inner surface of the tube. This uniform attack, however, is very rarely observed in practice. Occasionally, after prolonged service, the inner surface of a tube has been found to be covered with a thick film of copper. More frequently a thin film of copper is first formed, and the course of corrosion then becomes irregular both in speed and distribution, owing to causes dealt with under (B)

(B) In nearly every instance a condenser-tube fails in practice because active corrosion is confined to certain spots and leads to perforation of the tube. These spots generally appear to be distributed quite irregularly along the tube. They can be produced by any of the following conditions.

(*a*) *Local Irregularities in the Physical Condition of the Metal.*—A hard-drawn alloy is found to corrode less rapidly than the corresponding annealed metal. At the same time the hard-drawn metal is more liable to localised corrosion. This is almost certainly due to the presence of areas of specially strained metal, which, being more anodic than the rest of the metal, give rise to small local electromotive forces and so promote localised dezincification and pitting. It is found that wherever the metal has been drilled or filed corrosion tends to be more rapid and more "selective" in character.

Selective corrosion is frequently observed to commence along the furrows which are sometimes produced in the metal during the process of drawing. It is frequently found in practice that when a tube passes at all loosely through a diaphragm plate the vibration of the tube against the plate wears a furrow on the steam side of the tube, and that the hardening of the brass caused by this hammer action greatly accelerates local corrosion on the sea-water side of the tube. Localised dezincification and pitting also occur with an annealed tube. This may be due to local differences in the surface composition of the metal produced by the annealing and the subsequent treatment with acid. Possibly the physical character of the strained metal remains different from that of the surrounding unstrained metal, even after annealing has taken place.

Broadly considered, there does not appear to be very much to choose between the hard-drawn and the annealed metal. It is possible that the influence of local irregularities in the condition of the metal is confined to the early stages of the corrosive attack, and by producing pitting and unevenness of the surface, prepares the way for the operation of other factors of a directly chemical character. Local differences of temperature induced by an uneven distribution of the steam—as, for instance, when auxiliary steam-pipes are introduced directly into the condenser instead of into the main steam-pipe—promote dezincification locally. It is evidently a matter of first importance to secure even steam distribution by a suitable arrangement of diaphragms and baffle-plates. Local variations of temperature are also produced by the presence of porous deposits in the tubes.

(*b*) *Local Irregularities in the Chemical Conditions Prevailing at the Surface of Contact of the Metal and the Sea-Water.*—Wherever solution of the alloy, or of one of its constituents, is facilitated locally, as, for example, by a deposit of a catalyst such as zinc oxychloride, local electromotive forces will be produced.

Probably one of the most common causes of localised dezincification is the formation of a deposit of zinc oxychloride upon the surface of the brass. This salt promotes, it is thought, catalytically, the passage of zinc from the brass into the sea-water. It is always associated with a considerable proportion of zinc carbonate, which probably acts as a cement and serves to make the deposit strong and porous. The salt is only formed within certain conditions of temperature and salt concentration. It does not appear to be formed very readily in ordinary sea-water at temperatures below 50 deg. Cent. Probably it is formed readily at higher temperatures. It is formed most readily in diluted sea-water, but not in water which contains only one-sixteenth or less of the concentration of salt found in ordinary sea-water. It is not likely, therefore, that this salt will be formed in river water, but it will be formed readily in estuary water.

It is important to notice that once this salt is formed upon the metal it will continue to act even in ordinary sea-water or in fresh water. It is probable that this salt is formed upon the tubes in many cases before the vessel makes her maiden voyage—*i.e.*, in the estuary or dock water of her port of origin.

It seems to be impossible to prevent the formation of this salt, but much can be done to lessen the chance of its formation by keeping the temperature of the circulating water as low as possible. At the same time, whenever practicable, it is suggested that the zinc oxychloride be removed from the tubes by a charge of weak acid, just after the vessel has concluded her stay in waters which are likely to promote the formation of this salt. It has been found that this deposit is readily dissolved even by a weak inorganic acid, such as acetic acid. The salt is formed readily wherever the metal is in contact simultaneously with air and sea-water at a high temperature. Such conditions would occur along the water-line in a partially filled tube, and in certain cases where a bubble of air remains for a time in contact with the metal at 50 deg. Cent., or higher temperatures, even in ordinary sea-water.

(*c*) Corrosion may also be accelerated locally by contact with cathodic substances, such as coke or carbon.

A sufficiently good electrical contact must be established between the cathodic substance and the metal. In practice, satisfactory electrical contact is probably exceptional. It may be prevented by scale on the metal or by insulating material, for example, ferric hydroxide, collecting in the pores of the coke.

It is suggested that corrosion may be minimised:—

1. By keeping the temperature of the water as low as possible. This would be more easily accomplished if the water flowed through the separate sections of the condenser "in parallel" instead of "in series."

2. By making the flow of the water as smooth as possible—*i.e.*, free from foaming and churning. Possibly this could be accomplished by the use of small conical baffle-plates fixed with the point inwards at the entrance to each tube.

It is probable that much mechanical erosion of the tube ends would be prevented by filtering the water as efficiently as possible. In many cases this is attempted, but it is no doubt very difficult to filter efficiently such large volumes of water.

3. By removing any oxysalt as soon after it is formed as possible. This may be done with a brush when the condenser is opened up or by adding a suitable charge of acid to the circulating water, taking care that the supply of steam is shut off. This acid must be very dilute, so that it would readily dissolve the oxysalt without leading to any attack upon the metal itself.

It is possible that an annealed alloy would be have better than the corresponding hard-drawn alloy. At the same time it is necessary to bear in mind that most of the causes of corrosion considered in this report are external to the alloy itself, and are not necessarily affected by the physical condition of the alloy. Of the five alloys considered in this report none has proved to be entirely satisfactory.

70 : 30 brass would appear to be satisfactory in ordinary sea-water at temperatures below 50 deg. Cent. At higher temperatures, or in estuary water, it appears to be untrustworthy.

70 : 29 : 1 tin-brass resists dezincification better than the 70 : 30 brass, except in very dilute sea-water.

70 : 28 : 2 lead-brass resists localised and selective corrosion at all temperatures up to 60 deg. Cent. much better than either of the other brasses. Unfortunately, it is very severely attacked by diluted (*i.e.*, estuary) sea-water.

Phosphor-bronze behaves very well in ordinary sea-water and diluted sea-water if the temperature does not rise above 50 deg. Cent. At 60 deg. Cent. a white oxysalt is formed which promotes rapid selective corrosion of the tin. This salt does not appear to be formed at lower temperatures. The rate of "complete" corrosion is much greater than that of the other alloys, and may lead to pitting if accelerated locally by aeration or strain. In practice the metal would probably become protected by scale, and unless the temperature rose to 60 deg. Cent. it is unlikely that oxysalt would be formed. It is probable, therefore, that this metal would prove more satisfactory than any of the others considered, provided that all accidental causes of corrosion, such as churning of the sea-water or choking of the tube, can be prevented.

Aluminium-Copper.—Aluminium-copper dissolved very slowly in ordinary sea-water at all the temperatures considered, and is practically unaffected by carbon dioxide. Unfortunately, it is attacked very severely by diluted sea-water. Until a suitable non-corrosive alloy is discovered, corrosion can only be minimised by precautionary measures, such as those suggested above, and by the examination and cleaning of the tubes at frequent intervals, and more especially when the ship has been passing through water which is known to be unusually corrosive.

It is to be remembered that the only satisfactory method of testing the validity of conclusions based upon experimental work is to apply them to the solution of the actual problems that are constantly occurring in the experience of the engineer and the metallurgist. The results and conclusions of the experimental work should be, and have been, supplemented by careful and systematic comparison with the character and circumstances of the corrosion under practical working conditions. It is hoped that engineers and manufacturers will continue to assist the Committee in a very real manner by furnishing them with specimens of corroded tubes and accurate and full information bearing upon the conditions of service under which the corrosion occurred. The practical value of the laboratory work will be determined by the extent to which it can afford a reasonable explanation of such naturally occurring corrosion, and the success with which it can provide suitable means of preventing it.

In conclusion, it may be pointed out that almost the whole of the work of the Committee up to the present time has been directed towards examining the causes of corrosion. It appears to the authors that sufficient information has now been accumulated to enable a start to be made on the problem of protection against corrosion.

"ENEMY" FIRMS IN AUSTRALIA.—The Australian authorities, says the High Commissioner, have taken very active steps in the direction of dealing with "enemy" firms attempting to trade in the Commonwealth. A list giving the names of the black-listed firms is issued for publication.

COAL IN HOLLAND.—The quantity of coal imported into the Netherlands in 1914 was 16,264,950 tons, as compared with 20,466,229 tons in 1913, and 18,249,623 tons in 1912. Of the coal imported in 1914, 329,219 tons came from Belgium, 1,725 545 tons from Great Britain, 14,204,722 tons from Germany, and 5464 tons from other countries. The corresponding receipts from Belgium in 1913 were 512,176 tons; from Great Britain, 2,034,437 tons; from Germany, 17,919,596 tons; and 20 tons from other countries. The receipts from Belgium in 1912 were 555,840 tons; from Great Britain, 2,157,354 tons; from Germany, 14,535,632 tons; and from other countries, 1,000,797 tons. Of the coal imported in 1914, 11,281,782 tons were retained for consumption in the Netherlands, as compared with 13,734,843 tons in 1913 and 12,393,660 tons in 1912. Nearly all the coal imported into the Netherlands from Great Britain during the three years was retained for home consumption; but German coal was retained to the extent of only 9,400,654 tons in 1914, as compared with 11,446,579 tons in 1913 and 9,949,180 tons in 1912. Coal was exported from the Netherlands in 1914 to the extent of 8,752,655 tons, as compared with 12,381,551 tons in 1913 and 10,979,538 tons in 1912. It will be seen that the exports were largely made up from imports, re-exports accounting for the not inconsiderable balance.

THE ELECTROLYTIC METHOD OF PREVENTING CORROSION.*

By ELLIOTT CUMBERLAND.

THE writer has observed numerous instances of corrosive action for many years in different parts of the world, and has been impressed by the varying amount of corrosion which takes place when parts of metal structures are immersed in water; and how very much more rapid is the deterioration when dissimilar metals are used together in such structures. Those who are interested in the efficient maintenance of important engineering structures know that the question of corrosion is somewhat complicated, and realise that a much stronger force is at work than oxidation or rusting. Practically, all research and observation point to the fact that unless water is present, metals will not corrode in oxygen, and that the action of pure water or pure air on any metal is very slight.

The most widely held theory at the present day is that corrosion is due to galvanic or electro-chemical action. Therefore the writer wishes to confine his attention to the preservation of metallic structures in contact with water and other corrosive liquids, and, after considering cause and effect, to describe a method of overcoming this evil and incidentally of keeping the protected surfaces free from any foreign deposit. The galvanic action is due to the difference of electrical potential of the particles of the metal. The electro-negative particle is always protected at the expense of the electro-positive particle, and a small portion of the intervening water is decomposed into hydrogen and oxygen. Alloys of all descriptions suffer in this way, and the condition of the particles of these is a good subject for research. Many attempts have been made to render metals immune from corrosion, and great care is exercised in their manufacture to endeavour to prevent irregularity of composition.

Thermo-electric couples also exist, due to variation of temperature. Evidence of this is found on the water side of furnaces in boilers along the line of fire-bars, and much of the deterioration of hot-water pipes in heating systems is due to electrolytic action between the hot and cold portions.

Galvanic action occurs between the harder and softer portions of a similar metal. This is met with in parts of a structure which have been flanged, riveted, caulked, hammered, or stressed in any manner, either during manufacture or by reason of unequal working strains. The stressed parts are found to be electro-positive to the softer or normal portions. This action is very often met with in steam boilers; it is also particularly noticeable in the case of copper pipes when they form bends and have been subjected to hammering. It may appear as pitting over certain areas, or in grooving, according to the manner in which the material has been strained. Local corrosion is also prevalent near the flanges of pipes where brazing has affected the nature of the copper.

Fire-mains in warships suffer very much in this manner, and efforts have been made to overcome the trouble in these by fitting at intervals short lengths of cast-iron pipe which can be easily renewed. The cast iron being electro-positive to the copper, transfers the corrosive action to itself. The drawback to this method is that the protection is only temporary—while the surface of the iron is new and clean—subsequently, reversal of polarity occurs, as the oxide and products of corrosion are electro-negative to the copper.

The injection and discharge pipes used for circulating sea-water through the main condensers also suffer considerably from this corrosive action; especially in the case of battleships and large mail steamers fitted with turbine propelling machinery. The reason is that the connections between the condenser and the turbine are large and rigid, and in order to allow free expansion to the turbine-casing, the condenser is fitted with sliding feet. Therefore, where the inlet and discharge-pipes are comparatively short in length, strains are set up, and the result is severe corrosive action. In consequence, copper has been discarded for this purpose in battleships, and cast-brass pipes of greater thickness than the copper have been introduced to ensure a longer life. These are very expensive and difficult to manufacture; but the chief disadvantage is that they are stiff and more liable to fracture than the ductile copper pipes. Obviously the better course would be to retain the copper pipes, and render them immune from corrosive action.

It is well known that if two plates—one of zinc and one of copper—are placed in a liquid, a difference of electrical potential exists, the zinc being electro-positive to the copper. And also, that two pieces of the same metal—one having been strained or hammered, and the other in its normal state—being similarly immersed, show the former to be electro-positive to the unstressed portion. Further, if we consider the surface of an alloy containing segregated portions of its different constituents, these parts have differences of electrical potential in proportion to the position of the constituents on the galvanic or electro-potential scale. When the liquid forms the conductor or electrolyte, the flow of electrical energy is from positive to negative, and the metal from which the current enters the liquid suffers electro-chemical change in the form of corrosion. The reason corrosive action is more pronounced when metals are in contact with sea-water, is because this is a better electrolyte.

The extensive corrosive action which causes the failure of condenser-tubes manufactured from an alloy of copper and zinc is principally attributed to this action, and takes up various forms. In some instances it appears in the shape of minute holes right through the tubes, and in other cases patches of various dimensions become weakened, and ultimately develop cracks and break away. On examination it is noticed that the zinc has disappeared from the alloy, leaving the copper unsupported. This is generally termed "dezincification," and when it occurs locally the life of the tube is a very short one.

Instances have been recorded where the presence of carbonaceous matter in contact with the tubes caused perforations. This was the result of partially-burnt coal and ashes being drawn in by the circulating pump and remaining in contact with the tubes. In this case the carbon was electro-negative to both metals contained in the alloy, and galvanic action was set up, which resulted in damage to the tubes.

Quite apart from the considerable cost of effecting repairs to condensers and the inconvenience caused, it is of great importance that salt water should not enter the boilers by way of the contaminated feed, due to leaky condensers. If this occurs, any corrosive action which is present in the boilers is greatly accelerated. Care must also be taken that no particles of brass, copper, graphite, zinc oxide, or other electro-negative metals are allowed to enter the boilers, as they have the effect of producing severe corrosive action when in contact with the steel plates of the boiler, and this is increased by the perfection of their contact with the steel. While many inventors and investigators seek to solve the problem by finding a truly incorrodible alloy, the writer contends that this is almost impossible, and that the true solution lies in applying a method which renders all metals and alloys incorrodible.

The corrosion of all ferrous and non-ferrous structures may be lessened by connecting, in good electrical contact, a metal which is known to have a greater electro-chemical affinity for acids and oxygen than the metal of which the structure consists. When this is done the corrosive action is transferred from the structure to the auxiliary metal. Following Faraday's Law of Electrolysis, the more electro-positive metal is anode, and the structure cathode, and corrosion under these conditions can only take place at the anode.

The best protective metal to use is pure rolled zinc. This method is only temporarily effective, the reason being that the surface of the protective metal soon becomes oxidised, and in consequence rapidly loses its power to protect; therefore it must be renewed at frequent intervals, otherwise it becomes heavily coated with oxides, &c., and reversal of polarity will soon occur. If the deteriorated zincs are not renewed frequently, the result will be accelerated corrosion of the structure instead of protection. There are many disadvantages associated with this method of protection. For instance, 1 sq. ft. of zinc, when new, will only protect about 50 sq. ft. of immersed structural surface. This means a huge amount of zinc if one is contemplating the protection of the steam plant in an ocean liner, or, say, one of H.M. super-Dreadnoughts, which may have immersed boiler and condenser surface amounting to many thousands of square feet. And, added to this, every piece of zinc must be fitted in good metallic contact. The method of fitting these auxiliary plates of an electro-positive metal has been in vogue since the days of Sir Humphry Davy, and has become stereotyped by long use. There is no doubt that it is right in principle, but fails to protect completely, and if not frequently renewed causes detrimental reaction, as zinc scale has been tested and found to be electro-negative to many kinds of steel, iron, brass, Muntz metal, and Admiralty mixture for condenser-tubes.

After investigating numerous acute cases of corrosion and noting the various attempted remedies, it was obvious to the writer that the complete protection of all metals immersed in liquids was a simple matter, comparatively inexpensive and within the reach of all. He therefore devised and worked out a system whereby an unlimited supply of protective electrical potential could be used permanently to overcome all corrosive action. The apparatus consists of a low-tension dynamo generating continuous current at a pressure of 6 to 10 volts, and pieces of iron suspended in the water contained in the vessel to be protected and suitably insulated from it.

The first illustration (Fig. 1) shows the Cumberland process fitted to a surface condenser of the usual type, with the circulating water passing through the tubes. It will be noticed that the iron anodes L are supported by the steel stud B (Fig. 2) and insulated from the condenser door; these electrodes are connected through the adjustable resistance D and two-way switches E (Fig. 1) to the positive terminal of the generator.

The condenser itself is connected, as shown, to the negative terminal. An ampere meter C is fitted on the switchboard, and the supply of current to the electrodes can be regulated with the aid of the resistance coils D.

The common cause of failure of condenser tubes is galvanic action brought about in various ways, such as dissimilar metals in juxtaposition, the presence of carbonaceous matter in contact with the tubes, or difference of electrical potential, due to variations of temperature, &c. This action is neutralised by introducing a superior electromotive force from an external source, which overcomes the minor destructive currents due to these adverse conditions, ensuring that the flow of current is always from the inserted electrode through the liquid on to the surfaces to be preserved.

The above diagram (Fig. 3) shows how the system is applied to a Scotch marine boiler. The iron anodes, A, are supported by insulated brackets fixed to the main stays in the steam space, and extend between the tube nests; the immersed portions being kept clear of the internal parts of the boiler. They are connected through the insulated bolts B to the positive side of the circuit,

Fig. 2. CUMBERLAND INSTALLATION IN SURFACE CONDENSER

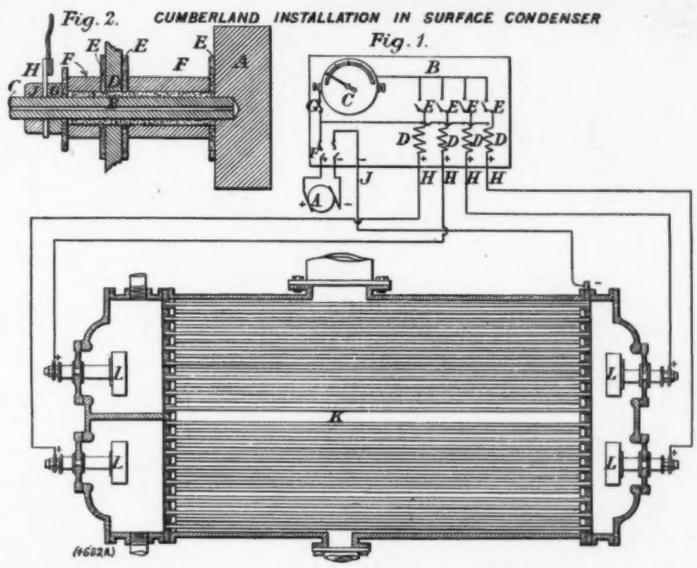
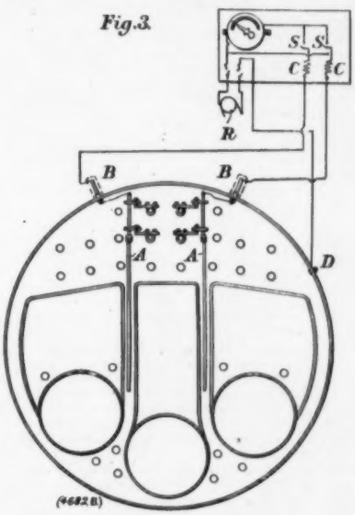


Fig. 1.

Fig. 3.



* Paper read before the Institute of Metals, on Wednesday, March 29, 1916.

and the exterior of the boiler at D is connected to the negative side. The current flows from the positive terminal of the dynamo to these electrodes, passes through the water, and returns thence to the negative terminal. The immersed portions of the anodes deteriorate, and these are made easily detachable for the purpose of renewing. Their life under usual conditions is about two years, and they are made from ordinary bar iron and mild steel.

In regard to the amount of current required to protect surface condensers, this varies slightly, but in extreme cases 1 ampere per 500 sq. ft. is found in practice to afford complete protection. The anodes L (Fig. 1) fitted in a surface condenser consist of cast-iron blocks 7 in. in diameter, 2 in. thick, each weighing 20 lb. Take, for instance, a condenser containing 6000 sq. ft. of cooling surface, the number of electrodes fitted would be six—three at each end—having a total weight of 120 lb. The amount of current supplied would be 2 amperes per electrode, giving a total of 12 amperes at 6 volts to protect the whole 6000 ft. of cooling surface.

In the case of boilers, where removal of scale has to be taken into account, the amount of current found necessary is rather more. For a single-ended Scotch marine type of boiler, 13 ft. 6 in. in diameter and 11 ft. long, with a heating surface of 2700 sq. ft., from 9 to 10 amperes would be sufficient; this is on the basis of 1 ampere to 300 sq. ft. In a case in which twelve Yarrow water-tube boilers were installed, the total heating surface was 49,500 sq. ft.—equal to 4125 sq. ft. per boiler. On the basis of 1 ampere per 300 sq. ft., 14 amperes per boiler was decided upon. The engineers on the ship found that this amount could be considerably reduced and all corrosion eliminated and heating surfaces kept clear of scale by using only 5 amperes per boiler; this works out at about 1 ampere per 800 sq. ft. of heating surface. The anodes in this case consisted of two 7 ft. lengths of 3 in. by $\frac{3}{4}$ in. bar-iron, fitted in the steam-drums slightly below the water level.

The writer has had the satisfaction of overcoming the most obstinate cases of corrosion when many other methods had been tried without success, and whilst effecting this discovered that the regular working of his system had a most remarkable effect in decomposing and removing hard scale from the heating surfaces of boilers, &c., and also prevented further formation. This phase of the subject is of great importance to engineers when considering fuel efficiency.

Sulphates and carbonates of calcium are the cause of nearly all scale troubles, and Rankine's figures give some idea of their non-conductive properties:—

Copper	0.4	Comparative resistances to passage of heat given by Rankine in his "Mechanics."
Wrought iron ...	1.0	
Slate	9.5	
Calcium carbonate	17.0	
Calcium sulphate	48.0	

Sulphate of calcium and magnesium hydrate form the hardest kind of scale, and recorded analytical averages of many specimens of hard scale show them to contain more than 50 per cent. of sulphate of lime. Those who are aware of the expensive methods which have been resorted to in endeavouring to eliminate this trouble of scale formation will be able to appreciate the value of a system which removes the existing non-conductors and prevents further deposits of scale or grease on the heating surfaces of boilers.

In order to deal in a simple way with the reason of non-formation of scale under the influence of this electrolytic process, it is necessary to remember that acids, bases, and salts may each be regarded as being composed of two parts—a positive radicle and a negative radicle. Positive radicles are so called because they can, under certain circumstances, unite with and carry charges of positive electricity. Negative radicles, in a similar way, can unite with and carry charges of negative electricity. The following list shows how various substances arrange themselves under the influence of the current:—

At the Anode.	At the Cathode.
Negative Radicles.	Positive Radicles.
Chloride	Hydrogen
Bromide	Sodium
Hydro-sulphide	Potassium
Nitrate	Ammonium
Chlorate	Calcium
Sulphate	Magnesium
Sulphide	Zinc
Oxide	Copper
Carbonate	Lead
Iodide	Iron

It is seen that hydrogen and sodium ions, among other positive radicles, seek the cathode, and are liberated at the surface of the structure, being protected, while the negative radicles—oxygen, chlorine, &c.—are directed to the anode.

On glancing down the list it will be observed that the component parts of calcium sulphate and calcium carbonate are separated, and cannot therefore combine at the heating surfaces, and bake on in the form of scale. In fact, some of the insoluble elements which originally formed scale can be blown out of the boiler in a finely-divided state. In dealing with old hard scale a certain amount of decomposition takes place, and it is rendered soft and spongy. The hydrogen forming on the metal underneath the scale loosens this, mechanically causing it to fall off. Further deposit of grease or foreign matter is prevented from adhering to the surface of the metal by this protecting film of hydrogen. The Cumberland process has removed hard scale of considerable thickness from the heating surfaces of boilers, and made it possible for the boilers to be kept in continuous use for a period of nine months, where previously it was necessary to have them cleaned out every three weeks.

It may here be asked why, if hydrogen acts in this way, the liberation of steam does not prevent scale formation? It certainly does remove loose portions, and if solid substances were laid on the surfaces it is probable that the steam bubbles would push them away. But when scale is formed on heating surfaces a chemical action takes place, due to high temperature assisting certain elements to combine, and the evolution of steam does not prevent this combination. When, however, these reacting components are directed apart by the electrolytic method, there is no such combination, and therefore no scale formation.

Another interesting phenomenon came under observation in the following manner:—An ammonia condenser was used in a large ice factory; it contained numerous iron tubes, through which sea-water was circulated. These had suffered from severe corrosion, and the circulation of the water was retarded by growth of shell-fish on the tube-plate and ends of tubes, thus considerably reducing the efficiency of the condenser. After the Cumberland method had been put into operation, not only did the corrosion cease, but the shell-fish and barnacles were also removed. The explanation of this is that hydrogen and sodium ions had been liberated on the protected surfaces, and this proved fatal to these marine organisms. The advantages of such a simple and inexpensive method of protecting all metals in contact with, or immersed in water or other corrosive liquids, are obvious to those who study efficient maintenance.

The Cumberland system described here has been put into practice on a large scale. A number of steamship companies have adopted it with success. Amongst the earliest was the Union Steamship Company, of New Zealand, who now have it in operation throughout their whole fleet. In this country, the White Star Line were the first to adopt it, and a number of their ships have it fitted to the boilers and condensers.

A steamer belonging to this firm has recently returned to port after being away as auxiliary cruiser for some thirteen months. Her boilers were found to be in excellent condition, being free from corrosion and scale; and her condensers, which previously gave much trouble from corroded tubes, are perfect, and not a single tube failed during this period. The results are considered to be so satisfactory that this company is not only installing the process in the boilers and condensers, but also in fresh and salt-water tanks. The R.M.S. Britannic is one of the first ships to be so installed. The Cumberland system is being tried by the British Admiralty in boilers.

COLONIAL AND FOREIGN ENGINEERING PROJECTS.

WE give below a few data concerning several colonial and foreign engineering projects, taken from the *Board of Trade Journal*. Further information on these projects can be obtained from the Commercial Intelligence Branch, Board of Trade, 73, Basinghall-street, London, E.C.

Australia: The Office of H.M. Trade Commissioner in Australia has forwarded copies of two Acts of the Victorian Legislature, dated December 23 last, enacting as follows:—(1) Act No. 2794 authorises the raising of moneys to the amount of 3,500,000*l.*, to be applied as follows:—3,000,000*l.* for the construction of railways and tramways and works connected therewith; 160,000*l.* for irrigation, water supply, drainage, and flood protection works in country districts; 240,000*l.* for public works and other purposes; and 100,000*l.* for works and buildings (other than maintenance) in connection with the State Primary Schools. (2) Act No. 2796 sanctions the issue and application of loans to the extent of 3,110,000*l.*, to be devoted to works in connection with the construction and maintenance of railways. A schedule to the Act provides for the distribution of this sum as follows:—800,000*l.* is allotted for additions and improvements to way and works; 800,000*l.* for rolling-stock equipment, machinery, and other works; 50,000*l.* for the purchase of railway stores; 800,000*l.* towards the electrification of the Melbourne suburban lines; and 660,000*l.* for the construction of new lines, including rolling-stock and work in connection therewith and surveys of proposed lines. The Sydney Office of H.M. Trade Commissioner in Australia reports an announcement by the Premier of the New South Wales Government that a Bill providing for the construction of the high-level bridge connecting the city of Sydney with the harbour, at an estimated cost of 3,000,000*l.*, was in the course of preparation, and would be introduced into the Legislative Assembly at an early date. The Engineer to the Public Works Department, however, states that the work of construction can not be commenced until after the war owing to the difficulty in obtaining the necessary materials.

South Africa: The Imperial Trade Correspondent in Johannesburg calls attention to the following statements in the issues of the *South African Mining Journal*, Johannesburg:—The Rand Water Board has decided to proceed with a modified scheme for supplying the Witwatersrand with water from the Vaal River. Originally the scheme was one for impounding 20,000,000 gallons of water and providing plant for pumping 10,000,000 gallons to the Rand. It has now been decided to proceed with the erection of the barrage on the original lines, but to install a plant capable of dealing with only 5,000,000 gallons. The cost of the scheme is estimated at 758,000*l.*, including an amount of 42,000*l.* already expended for surveying, &c. Electrical materials are being purchased as fast as they are received in Johannesburg. The same may be said of timber and all building materials, for which the demand is quite steady. In Johannesburg the pinch is beginning to be felt over the shortage of certain kinds of steel; for example, 3-in. steel turned shaftings are exceedingly scarce. There is also a great scarcity of wrought-iron pipes from 1 in. to 4 in., and the mines are securing what is available, as the regulations about spraying underground are being strictly enforced, which means that an immense quantity of piping is used in each producing mine.

Portugal: The *Diario do Governo*, Lisbon, publishes the text of conditions under which João Pedro Vierling, or a company to be formed for the purpose, is authorised to construct and work, for a period of 99 years, a railway from Tomar to Nazaré. The line, after leaving Tomar, will pass through Agroal, Ourém, Reguengo, Batalha, Porto de Mós, Aljubarrota, and Alcobaça, and thence to Nazaré; a branch line will connect with the town of Leiria. The railway will be of metre gauge, and a period of three years is allowed for its completion. During the period of the concession all material, both fixed and rolling-stock, required for the construction and working of the railway will be granted duty-free admission, provided such material is not able to be satisfactorily supplied by Portuguese workshops. H.M. Consul at Lisbon writes that firms desirous of tendering for railway material in connection with the above-mentioned contract might communicate with Mr. Vierling, whose address may be obtained by United Kingdom manufacturers on application to the Commercial Intelligence Branch. In making application the reference number (102) should be quoted. The *Diario* also notifies that the Portuguese Government has approved the projects and estimates for port works at Setubal, representing a total cost of 1,302,360 escudos (about 195,000*l.* at current rate of exchange).

Spain: The *Gaceta de Madrid* notifies that sealed tenders will be received at the Dirección General de Obras Públicas, Ministerio de Fomento, Madrid, up to 11.30 a.m. on April 15, for the supply of four locomotives required for the State railway from Betanzos to Ferrol. A preliminary deposit of 25,000 pesetas (about 1000*l.*) is required to qualify any tender. Foreign competition will be admitted, but local representation is necessary. The *Gaceta* also notifies that tenders will be opened on April 12, at the offices of the Consejo de Administración del Canal de Isabel II., Calle de Alarcón, 7, Madrid, for the construction of a drainage canal in connection with the Isabel II. Canal scheme. The estimated cost of the works to be carried out under the present contract is 2,488,286 pesetas (about 99,500*l.*). Although this contract will probably be awarded to a Spanish firm, nevertheless the carrying out of the works may involve the purchase of some materials outside Spain. The *Gaceta* further publishes a notice, issued by the Ministerio de Fomento, approving the distribution of a credit of 7,287,354 pesetas (about 291,500*l.*) for expenditure, during the current year, on hydraulic works in connection with various land-drainage and canal, &c., schemes.

OUR COAL ABROAD.—Shipments of coal from the United Kingdom still show weakness. The quantity exported in February was 3,086,695 tons, as compared with 3,629,490 tons in February, 1915, and 3,725,877 tons in February, 1914. France was almost the only country to which increased deliveries were made in February. The aggregate exports to February 29 this year were 6,257,895 tons, as compared with 7,242,453 tons and 11,520,647 tons in the corresponding periods of 1915 and 1914.

MODERN INDUSTRIAL FUEL.—The second issue of *A Thousand and One Uses for Gas*, a monthly publication of the British Commercial Gas Association, deals with the applications of gas as a fuel for industrial purposes. The particular processes mentioned therein affording a field for the employment of the gas-furnace are glass manufacture, stereo-metal melting, soft-goods boiling, heating acids in vats, evaporating and stoving, roasting ore, sugar-boiling, caramel-toasting, and glue-melting. These are, of course, only a few of the many branches of industry in which gas has already popularised itself as a fuel, but a good idea of the multifarious uses to which it can be put in any particular trade is gained from an enumeration at the end of the article, which shows that gas is employed in the three trades of motor engineering, printing and bookbinding, and confectionery, for no less than forty different purposes.

NEW NUMBERING OF PATENT SPECIFICATIONS.—The first abridgment under the new system is published in the *Official Journal* (*Patents*), dated March 15. This gives rise to certain difficulties in the matter of priority of inventions which might well be pointed out now. The specification was filed on January 3, 1916, and the documents immediately became open to inspection (because the invention was made abroad, and application lodged here claiming the foreign priority), and could have been examined by anyone. The question whether, unless actual inspection be proved, this could be considered sufficient publication to deprive a subsequent inventor of priority of invention has never been satisfactorily settled. Under the new system, the abridgment being very quickly prepared, there is a definite publication in print soon after the application had been lodged. This is a very different publication from that due to the deposit of a set of papers at the Patent Office, which can be inspected at that particular place only. There then arises the point, Does the abridgment disclose the whole of the invention, or at least sufficient to take away subject matter from a possible later inventor? But in any event it will be appreciated that inventors must now very carefully take into account the publication of the abridgments of applications of foreign origin.